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The Potential Impacts of Climate Change on Recreational Fishing in Northern Ontario

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The Potential Impacts of Climate Change on Recreational Fishing in Northern Ontario

Len M. Hunt and **Jeff Moore**

Centre for Northern Forest Ecosystem Research

Ontario Ministry of Natural Resources
1235 Queen Street East
Sault Ste. Marie, Ontario
Canada P6A 2E5

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Fax: (705) 946-2030
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Summary

Based on angling diary responses, we developed predictive models capable of assessing how various climate change scenarios may affect recreational fishing. Northern Ontario anglers from the Wawa and Thunder Bay areas were included in our analyses. Our models are capable of assessing changes to both the availability of fishing alternatives and the attractiveness of these alternatives based on the amount, timing, and location of fishing trips by these resident northern Ontario anglers. Model utility is illustrated through a scenario whereby lake trout *(Salvelinus namaycush)* is extirpated from waters around Thunder Bay. Model results have some important implications for estimating the impacts climate change on recreational fishing:

- Changes in ice cover on lakes in early April are not likely to affect participation in recreational fishing by resident northern Ontario anglers.
- Maximum daily temperatures appear to have little effect on the decisions of northern Ontario anglers to participate in recreational fishing.
- Precipitation has a strong and negative effect on northern Ontario anglers' decisions to participate in day fishing trips.
- Culture and tradition have the strongest effects on the fishing participation decisions of northern Ontario anglers and it is doubtful if climate change will change this (e.g., reduced fishing after Labour Day weekend).
- Walleye *(Stizostedion vitreum)* is the most important species to northern Ontario anglers and any changes to the availability or abundance of walleye will greatly affect decisions by anglers on when, where, and how often to fish.
- Other fish species provide important fishing opportunities to northern Ontario anglers when the walleye season is closed. Therefore, any change to the availability and abundance of rainbow trout *(Oncorhynchus mykiss)* while the walleye season is closed will likely have a large negative impact on fishing participation by resident anglers.
- Some northern Ontario anglers target fish species other than walleye such as lake trout, brook trout *(Salvelinus fontinalis)*, rainbow trout, smallmouth bass *(Micropterus dolomieu)*, and northern pike *(Esox lucius)*. Consequently, any change to the availability or abundance of these species may lead to anglers concentrating their fishing effort in fewer locations (i.e., resource substitution) or targeting other fish species (i.e., activity substitution).
- Using a scenario model, it is estimated that the loss of lake trout opportunities from May 1 to September 30 for Thunder Bay area anglers will likely decrease recreational fishing activity by about 5,400 days (2.1% decline in total days) resulting in about a $175,000 per year reduction in the economic value of fishing.

Résumé

En nous fondant sur les réponses des pêcheurs à nos questionnaires mensuels, nous avons élaboré des modèles de prévision capables d'évaluer les répercussions de différents scénarios de changement climatique sur la pêche récréative. Nos analyses ont porté sur les pêcheurs de Wawa et de Thunder Bay. Nos modèles peuvent évaluer les changements dans la disponibilité d'activités de remplacement de la pêche et de leur attractivité en fonction du nombre, du moment et du lieu des excursions de pêche entreprises par les résidents du Nord de l'Ontario qui pratiquent la pêche. L'utilité de ces modèles est illustrée par un scénario dans lequel la truite grise *(Salvelinus namaycush)* est éliminée des eaux entourant Thunder Bay. Les résultats obtenus par ces modèles ont d'importantes implications sur l'estimation des incidences du changement climatique sur la pêche récréative :

- Les changements dans la couche de glace sur les lacs au début d'avril ne devraient pas avoir des répercussions négatives sur la participation des résidents du Nord de l'Ontario à la pêche récréative.
- Les températures quotidiennes maximales semblent avoir peu d'effets sur les décisions des pêcheurs du Nord de l'Ontario quant à leur participation à la pêche récréative.
- Les précipitations ont un effet négatif considérable sur les décisions des pêcheurs du Nord de l'Ontario quant à leur participation à une excursion de pêche d'une journée.
- La culture et les traditions ont les effets les plus considérables sur les décisions visant la participation des pêcheurs du Nord de l'Ontario et il est peu probable que le changement climatique modifie cela (p. ex., diminuer la pêche après la fin de semaine de la fête du Travail).
- Le doré jaune *(Stizostedion vitreum)* est l'espèce la plus importante pour les pêcheurs du Nord de l'Ontario et tout changement dans la disponibilité ou l'abondance de ce poisson aura une incidence sérieuse sur les décisions des pêcheurs quant au moment, le lieu et la fréquence de leurs sorties de pêche.
- D'autres espèces de poisson offrent aux pêcheurs du Nord de l'Ontario d'importantes occasions de pratiquer leur activité quand la saison du doré jaune est fermée. Par conséquent, tout changement dans la disponibilité et l'abondance de truite arc-en-ciel *(Oncorhynchus mykiss)* durant cette période aura probablement une grande incidence négative sur la participation des pêcheurs de la région à leur activité.
- Certains pêcheurs du Nord de l'Ontario ciblent des espèces de poissons autres que le doré jaune comme la truite grise, l'omble de fontaine *(Salvelinus fontinalis)*, truite arc-en-ciel, achigan à petite bouche *(Micropterus dolomieu)*, et le grand brochet *(Esox lucius)*. Par conséquent, tout changement dans la disponibilité ou l'abondance de ces espèces peut mener les pêcheurs à concentrer leurs efforts sur un nombre d'emplacements plus restreint (c.-à-d. : substitution de ressource) ou à cibler d'autres espèces de poissons (c.-à-d. : activité de remplacement).
- La perte de la possibilité de pêcher la truite grise du 1er mai au 30 septembre par les pêcheurs de la région de Thunder Bay diminuera vraisemblablement la pêche récréative d'environ 5 400 jours (une chute de 2,1 % du total des jours), entraînant une réduction de la valeur économique de la pêche d'environ 175 000 $ par an.

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1. Introduction

Climate change has the potential to affect almost all aspects of people's lives including their work and leisure activities and their health. These aspects are interrelated as any change to one aspect may also affect the others. For example, health changes may affect the types of leisure and work activities that one can pursue and changes to employment may negatively affect health and leisure. Even impacts to leisure activities may affect the physical and emotional well-being of individuals and the economic benefits that others accrue from their leisure pursuits. Potential climate change impacts on leisure activities are likely greatest for outdoor leisure activities such as fishing, canoeing, hunting, and wildlife viewing.

Tourist operators and many individuals involved in the service sector benefit economically from recreational activities pursued by recreationists and tourists (defined as individuals who take overnight trips of a significant distance (e.g., 40 km or more) from their primary residence) in outdoor settings. Impacts to these outdoor settings may affect the vitality and health of communities that partially depend upon expenditures by tourists, tourist operators and recreationists.

Much research has focused on the benefits of participation in outdoor recreation activities (e.g., Driver et al. 1991). Researchers typically view the pursuit of outdoor recreation activities as a means to achieve desired psychological outcomes such as relaxation and escape (Driver and Tocher 1970). Any changes that affect outdoor recreation activities, therefore, may affect the health and well-being of individuals.

Climate change may impact outdoor recreation by altering either the availability or the attractiveness of recreational opportunities. These changes may influence the frequency, timing, and location of outdoor recreation trips by recreationists.

The availability of recreational opportunities may be affected through changes to resources that are necessary to pursue outdoor recreation activities. For example, a shorter winter season with less snow and ice cover has the potential to affect the locations and timing of winter activities such as skiing, snowmobiling, snow shoeing, and ice fishing. Most research on climate change and outdoor recreation has focused on potential impacts on the availability of winter (e.g. Breiling and Charamza 1999, Irland et al. 2001, Scott 2003, Scott et al. 2005) and water-based (Bergmann-Baker et al. 1995, Wall 1998, Irland et al. 2001, Scott 2003) recreational opportunities.

Changes to climate may also alter the attractiveness of outdoor recreational opportunities through weather[1] and site attractiveness. Given that most recreational activities have an ideal range of weather conditions (Crowe et al. 1973, 1977a, b), it is likely that changes to weather will influence participation in a given activity. A few studies (Dwyer 1988, Provencher and Bishop 1997, Brandenburg and Arnberger 2001, Provencher et al. 2002, Moeltner and Englin 2004, Richardson and Loomis 2004, Baerenklau and Provencher 2005, Dewar 2005, Loomis and Richardson 2005) show that weather affects participation decisions of individuals for a variety of recreational activities.

Site attributes that determine the attractiveness of recreational settings (e.g., fish populations to anglers) may also be affected by climate change. In many cases, these changes to site attributes vary over the range of recreational settings. Confronted with these changes, recreationists may decide to substitute the activity or the resource (Shelby and Vaske 1991). For example, declining populations of fish species that require colder waters may lead anglers to substitute the resource (i.e., travel further north to access these coldwater fisheries) or the activity (i.e., target other fish species). A vast amount of research has examined the importance of characteristics that affect the site choices by outdoor recreationists (see next section).

This research focuses on the potential impacts of changes to the temporal and spatial attractiveness of recreational fishing opportunities. Temporal changes involve assessing how weather is likely to impact northern

[1] We define weather as the actual atmospheric conditions at a given time while climate is the expected atmospheric conditions for a given time. Measures such as temperature and precipitation provide indicators of the atmospheric conditions.

Ontario anglers' decisions to participate in fishing (i.e., activity substitution). Spatial changes examine how changes to attributes of site attractiveness, such as fish species availability and abundance, result in resource and activity substitution. We use a repeated nested logit model (Morey et al. 1993) that accounts for the processes that lead to participation and fishing site choices of anglers and develop a general model that exhibits great flexibility at forecasting the likely effects of a range of scenarios. Other researchers may use this model to predict the consequences of climatic impacts on weather, fish populations, or other attributes on the amount, timing, and spatial pattern of fishing trips by anglers.

We also assess changes to ice conditions required for ice fishing and contrast participation rates by anglers during the transition of ice fishing to open water fishing opportunities in April to estimate whether shorter winter seasons are likely to affect participation rates in recreational fishing.

This report includes a section in which we discuss the importance of recreational fishing and past relevant related research, followed by a section that presents the data and methods used for the research. The descriptive analyses and results from the repeated nested logit model are provided in the fourth section. Model forecasts are showcased in section five through a modelled scenario on lake trout *(Salvelinus namaycush)* extirpation from Thunder Bay area lakes. Finally, we discuss the management implications of our research.

2. Recreational Fishing and Climate Change

This section provides information related to climate change and recreational fishing. First, we provide a rationale for studying climate change and recreational fishing in Canada. Second, we describe the modelling approach that others have used to understand and predict the choices of anglers for fishing trips and fishing sites. Finally, we discuss the few research studies that have used these models to examine issues of climate change or weather.

Recreational fishing is an important outdoor recreational activity for Canadians with about 4.2 million Canadians over the age of 15 participating in recreational fishing in 1996 (DuWors et al. 1999). The activity is also very important to northern Ontarians, many of whom view recreational fishing as an activity central to their life.

The importance of recreational fishing to Canadians and others has led to much social science research on this activity and those who pursue it. Especially relevant from a climate change perspective are the studies that have attempted to understand and to predict angling behaviours. While different theories for recreational behaviours exist, this study applies the random utility theory (Thurstone 1927).

Contemporary interpretations of random utility theory (Manski 1977, Ben-Akiva and Lerman 1985) assume that anglers will select the one most attractive fishing site from a possible set of fishing sites (i.e., maximize utility). Researchers use statistical models and data about sites chosen by anglers to estimate weights that help scale various attributes (e.g., travel distance, expected catch) into a utility (attractiveness) index. Since researchers do not know and cannot model all aspects that describe where and when anglers will fish, they introduce uncertainty into the utility index estimates for each site. This uncertainty leads to a forecasting model that only predicts the probability that an angler will select a particular fishing site. These choice models allow researchers to assess how many different scenarios are likely to affect angling behaviours.

Researchers have conducted many studies of angling behaviours using random utility theory. Hunt (2005) provides a thorough review of over 50 peer-reviewed studies that have examined anglers' fishing site choices. His review identified travel costs, fishing quality, environmental quality (e.g., water quality), facility development (e.g., boat launches), expected encounters with other anglers, and regulations[2] as important attributes that affect the attractiveness of fishing sites. While the importance of these attributes is self-evident, it is often difficult to identify suitable measures for these attributes at each fishing site.

[2] While regulations could affect the availability of a fishing site, most regulations do not prohibit fishing on a water body.

Forecasts from site choice models are of limited value since they do not predict how different scenarios are likely to affect the number of fishing trips. Researchers address this limitation by employing one of two assumptions (Hunt 2005). First, researchers may assume that anglers select the number and timing of fishing trips before the fishing season. This assumption permits researchers to predict fishing trips from a count-based, limited dependent variable model such as Poisson that includes the expected maximum utility from the set of fishing sites as an attribute (i.e., the models link site and participation choices). Second, researchers may assume that anglers make daily or periodic decisions about fishing participation over the course of a fishing season. The repeated nested logit model (Morey et al. 1993) provides one way to model this assumption of participation by adding another level (nest) into the choice decisions. One can think about this model as a sequential choice decision. The first decision for an individual is whether to participate in fishing on a given day. The second is where to fish on that day. Since participation depends upon the expected maximum utility from the site choice portion of the model, the model provides an effective link between changes to site-level attributes and participation decisions.

The expected maximum utility of the available fishing sites, angler characteristics and daily characteristics are all likely to influence the decision to participate in fishing on a given day. Hunt's (2005) review suggests that the frequency of fishing participation is higher for individuals who are males, are older, live in rural residences, are Caucasian, are unemployed, and have children. He also noted that individuals who own boats, have fished longer, and take trips with their families, fish more often than their counterparts.

Although the repeated nested logit model provides a suitable tool to assess the potential impacts of weather on daily participation decisions for recreational fishing, we are only aware of the work of Provencher (Provencher et al. 2002, Provencher and Bishop 2004, Barenklau and Provencher 2005) who used a type of repeated nested logit model to assess the effect of weather conditions on the participation decisions of anglers[3]. That study focused on the decisions of Green Bay, Wisconsin anglers to fish on Lake Michigan. They found that an angler's decision to fish on a given occasion increased as wind speed decreased and temperature increased.

Researchers may also use the repeated nested logit model to examine the consequences of changes to site characteristics that result from climate change scenarios on fishing. Ahn et al. (2000) used a repeated nested logit to examine recreational fishing of 1996 North Carolina fishing licence holders in the southern Appalachian Mountains. These authors predicted that warmer stream temperatures and corresponding decreases in dissolved oxygen would lead to 80 to 90% of brook trout *(Salvelinus fontinalis)* streams in North Carolina and Virginia becoming unsuitable for brook trout. They expect that this change in trout availability will reduce the economic welfare of North Carolina anglers by between $61 and $584 million per year. This result implies that North Carolina anglers would be prepared to pay $61 to $584 million to avoid the loss of brook trout habitat.

Pendelton and Mendelsohn (1998) used a site choice model (i.e., without participation decision) to investigate how expected climatic changes on trout and pan fish populations and expected catch rates would affect the economic welfare of anglers from the northeastern United States[4]. Without considering any changes to fishing participation, the authors concluded that a doubling of atmospheric carbon dioxide would result in an economic welfare loss of between $4.6 and $20.5 million. Again readers may view the change to economic welfare as the willingness of these anglers to pay to avoid the changes to trout and pan fish populations. Of course, improved catch rates for northern pike *(Esox lucius)*, walleye *(Stizostedion vitreum)*, and whitefish *(Coregonus clupeaformis)* would offset some, if not all, of this loss.

The research by Ahn et al. (2000) and Pendelton and Mendelsohn (1998) demonstrates the flexibility of choice models to predict angling behaviours and corresponding changes to economic welfare that result from climate change scenarios[5]. It is possible, therefore, for other researchers to use these choice models to investigate the likely effects of various climate change scenarios on anglers' behaviours and the economic value of recreational fishing.

[3]Another study by Provencher and Bishop (1997) used a structural equation model to examine participation decisions of anglers and weather characteristics.
[4]These anglers included licence holders from Maine, New Hampshire, Vermont, and New York except for New York city.
[5]Layton and Brown (2000) used a choice model based on stated intentions to investigate support for various climate change scenarios policies among Colorado residents.

3. Data Collection Methods

Our research focused on anglers from the Thunder Bay and Wawa areas during one open water season (April 1 through September 30, 2004). The use of these two different study areas allowed us to assess whether participation and site choice processes operate similarly in these very different locations. The focus on open water fishing season was based both on the popularity of open water fishing and pragmatic reasons; for example, the number of accessible waters is much higher during ice cover, making sampling more difficult.

The site choice models were estimated by comparing attributes at heavily chosen fishing sites with those of infrequently chosen fishing sites. Data about the pattern of fishing site choices were obtained from an angling diary program conducted with residents from the Thunder Bay and Wawa areas.

A consultant was hired to contact residents from the Thunder Bay and the Wawa area (i.e., the towns of Dubreuilville, Hawk Junction, Manitouwadge, Wawa, and White River) in March 2004. The consultant asked all individuals who were intending to fish in 2004 to participate in a short telephone survey that asked questions about years fished, number of days fished last year, fish species preferences, vehicle and equipment ownership, and age (see Hunt 2006 for results). After completing the short telephone survey, individuals were asked if they would participate in the angling diary program. Of the 1,454 anglers who completed the telephone survey, 1,005 agreed to participate in the angling diary program. By using this two-step approach for recruiting individuals to the diary program, it was possible to assess the degree of non-response bias (Dillman 2000) in our sample (i.e., whether differences existed between anglers who did and did not complete the angling diaries). This assessment revealed that while no response bias existed among the Wawa area anglers who completed the diaries, Thunder Bay area anglers who completed the diaries were more avid anglers than non-respondents.

Each angler who agreed to participate in the angling diary program was mailed a token fishing plug and a diary that asked for some basic information about cottage and camper ownership, motivations for fishing, and importance of various information sources for learning about new fishing opportunities. The diary also asked each individual to record details about his/her April and May fishing trips including the timing, duration, and trip contexts (e.g., whether the trip was taken as part of a longer trip from home). In late May, all anglers were contacted by mail, asked to return their April and May diary, and provided with a new diary for June and July and an entry ballot to win one of ten $100 gift certificates from two popular retail stores. In mid June, we contacted all non-respondents by phone to encourage their response. At the end of July, we again contacted the anglers by mail, provided a new diary and entry ballot for a draw, and asked them to return their June and July diary. At the end of September, we again provided anglers with an entry ballot for a draw and asked them to return the diaries. Final contacts with non-respondents were made by telephone to collect information about fishing trips.

About 50% of the anglers who agreed to the diary (n=498) provided usable trip information in all three diaries. The response rate was higher for Thunder Bay (53.1%) than Wawa (43%) area anglers. Another 8.9% of anglers provided usable information about some of their fishing trips.

The 347 Thunder Bay area anglers who completed the angling diaries reported taking 2,262 fishing trips that covered 4,625 days. The 151 Wawa area anglers reported taking 996 fishing trips over 1,474 days[6]. The Wawa area anglers reported fishing for more hours per day (4.0) on average than did Thunder Bay area anglers (3.6).

Diary participants reported taking many different types of fishing trips (see Table 1). The site choice models were estimated only from similar trip contexts. These contexts included day fishing trips that were not to private accommodations and not part of a longer trip from home and similar multiple day trips with the added caveats that the trip was for less than seven days and primarily for fishing. This resulted in inclusion of about three quarters of Wawa area and one-half of Thunder Bay area trips for estimating the site choice model. Various other trip contexts were included as alternatives in the fishing participation choice models.

[6]The relatively small population in the Wawa area restricted sample size relative to the Thunder Bay area.

Table 1. Fishing trip types (%) by diary respondents location in northern Ontario for 2004 open water season.

Trip type	Wawa	Thunder Bay
Day trip, not to private accommodation, and not part of longer trip from home	66.57	39.92
Two- to six-day trip, not to private accommodation, not part of longer trip from home, and for primary purpose of fishing	10.94	11.01
Seven or more day trip, not to private accommodation, not part of longer trip from home, and for primary purpose of fishing	0.30	0.40
Day trip to private accommodation	6.12	8.31
Multi-day trip to private accommodation	9.74	21.88
Day trip, not to private accommodation, but part of longer trip from home	4.02	8.44
Multi-day trip, not to private accommodation, but part of longer trip from home	1.51	2.43
Multi-day, not to private accommodation, not part of longer trip from home, but for some other purpose than fishing	2.81	5.92
Air accessible fishing trip	0.80	1.37
Unknown length of trip	0.0	0.31
Total trips	*996*	*2,262*
Total days of fishing	*1,474*	*4,625*
Average hours fished per day	*3.98*	*3.56*
Sample size	*151*	*347*

Source: Hunt (2006)

The site choice and participation models were based only on trips completed from May 1 to September 30, 2004. Eliminating the April trips was necessary to avoid modelling both ice and open water fishing trips with the same model.

A second data source needed to estimate a fishing site choice model is an inventory of available fishing sites. The spatial scale for this inventory was determined primarily from responses provided by the diary participants but was reduced slightly to limit the number of fishing alternatives in the model (e.g., some anglers took fishing trips as far away as British Columbia).

Figures 1 and 2 illustrate the two study areas. For the Thunder Bay area, the spatial extent of the modelled area was slightly smaller than the area for which site information was collected. The effective study area for Thunder Bay accounted for 96.6%, while the Wawa area accounted for 95.8% of modelled fishing trips.

Rather than relying on an *ad hoc* narrowing approach to limit the number of sites in the choice set (e.g., Parsons and Hauber 1998), the set of relevant sites included those that were directly or indirectly (i.e., boat navigation or popular portage routes) accessible from a road or trail. Several sources, including government databases, non-government fishing maps, and local knowledge from OMNR Conservation Officers and resident anglers, were used to identify a set of access points in both the Thunder Bay and Wawa areas.

While including local knowledge and other inventory data greatly benefited the project, this data required field validation. During the summers of 2003 and 2004, we visited every possible access point in the Thunder Bay

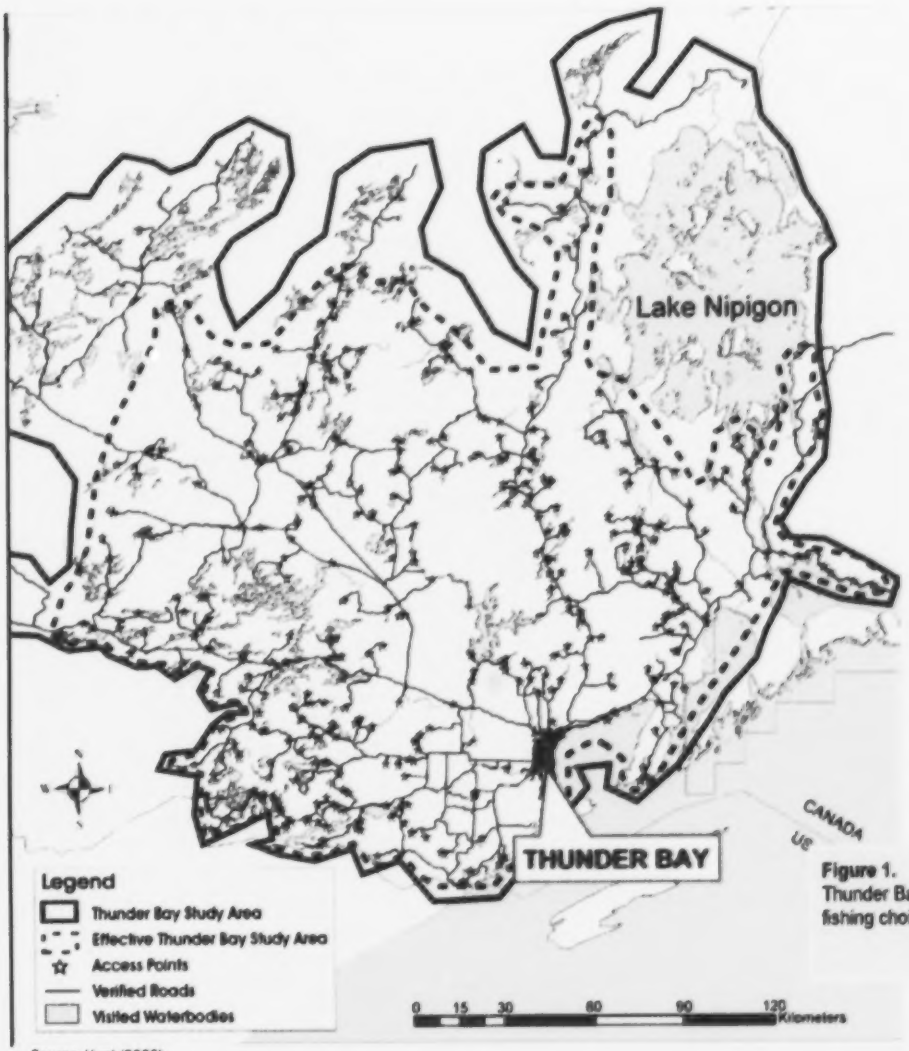


Figure 1.
Thunder Bay recreational fishing choice study area.

Source: Hunt (2006)

and Wawa areas. Over 1,000 access points, 629 in Thunder Bay and 406 in Wawa, were visited. Since some of these fishing sites involved access to the same waters or were in areas that received very few trips, we used 431 and 328 of these fishing sites as alternatives for the fishing site choice models for Thunder Bay and Wawa, respectively. When reducing the number of fishing site alternatives on water bodies with multiple access points, we chose those that were easier to access (i.e., better quality roads) and had better amenities (e.g., a boat launch). We also included the logarithm of the number of access points as an independent variable in the fishing site choice models.

The field visits helped to validate the existence and location of access points in the database and provided an opportunity to populate measures for many attributes that may affect an angler's choice of a fishing site. During each visit, a site inventory was completed that included spatial and non-spatial information. Of importance was information related to road quality, measured along a continuum that included paved roads, gravel highways, gravel roads, general trails, and walking trails. It was anticipated that each road/trail type would induce a different cost to the anglers. Other potentially important information collected at the sites included the presence and quality

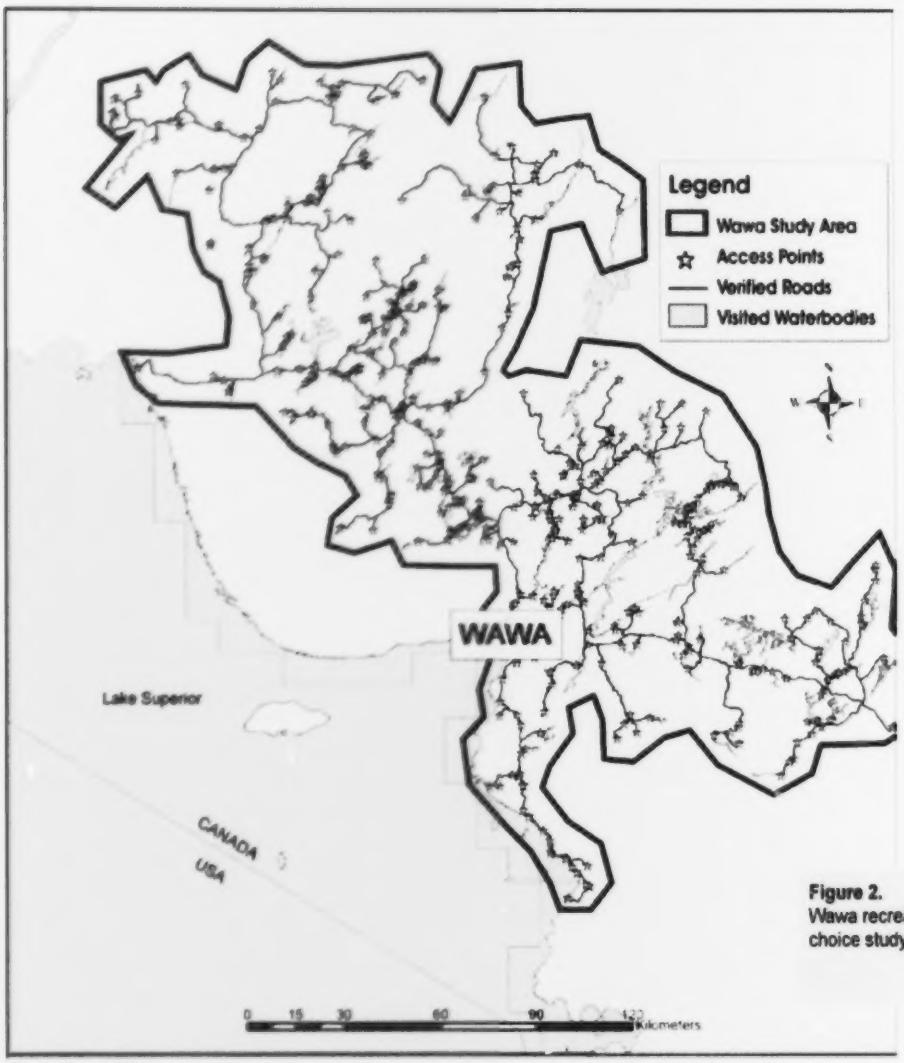


Figure 2.
Wawa recreational fishing choice study area.

Source: Hunt (2006)

of boat launching facilities; the availability and size of campgrounds, the presence of outhouses, picnic tables, and garbage cans; information about the water and forested environment; presence of beaches; presence of litter; and use levels on the day of inspection. Spatial data about the roads, campsites, access points, and signage were also collected.

The participation model includes information about daily weather conditions and characteristics of individual anglers. Data were collected on both the forecast and actual weather conditions for each day from April 1 through September 30, 2004 for the Thunder Bay and Wawa areas. Forecast weather data were obtained from the daily weather reports contained in the Chronicle Journal, and were supplemented by forecasts from Environment Canada when newspaper forecasts were unavailable. While it is possible that anglers would consult different weather forecasts, most media outlets base their forecasts on those provided by Environment Canada. Forecast weather variables included: (i) high temperature; (ii) wind speed; (iii) probability of precipitation; and (iv) weather conditions (i.e., sunny vs. cloudy, rain).

Actual weather data, obtained from the Environment Canada's National Climate Archive (http://www.climate.weatheroffice.ec.gc.ca), included hourly readings for temperature, wind speed, and weather conditions (e.g., clear, cloudy, rain) between 6:00AM and 9:00PM. Actual weather variables used in the initial participation models included: (i) maximum daily temperature; (ii) maximum daily wind speed; (iii) proportion of day with cloud cover (excluding rain); (iv) proportion of day with rain.

Information about angler characteristics was obtained through the recruitment telephone interview and responses to questions in the diaries. Variables in the participation model included ownership or access to private cottages, ownership of four-wheel drive trucks, ownership of all terrain vehicles, and years of fishing experience.

We used a repeated nested logit model to analyze the data. The stepwise approach is described in conjunction with results in following section. Model details are provided in Appendix I. Readers interested in the analytical details should consult Hunt (2006).

4. Analysis Methods and Results

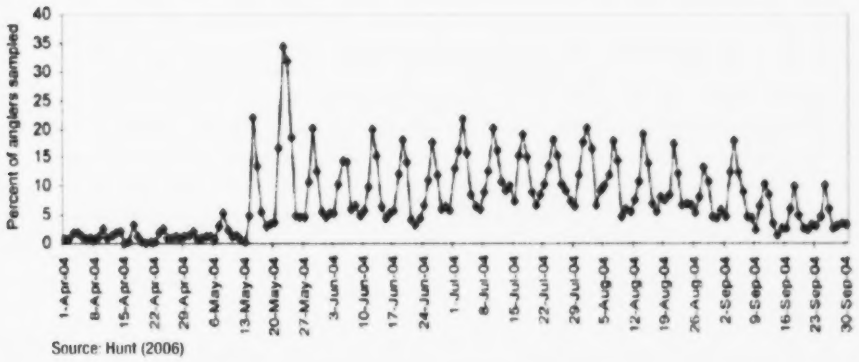
Before presenting the results from the repeated nested logit model, we provide some descriptive information. Subsection 4.1 illustrates fishing trends from the angling diaries. The following subsection examines the weather conditions from the open water fishing season in 2004. The third subsection examines the relationship between forecasted and realized weather, followed by results from the site and participation choice models.

4.1. Angling participation descriptive information

The angler diaries revealed many patterns of angler participation in northern Ontario. These patterns included differences in daily participation rates of fishing and differences in the attention focused on various fish species. This information is essential to assess the likely impacts that climate change may have on recreational fishing in northern Ontario.

Figures 3 and 4 show the daily participation rates for fishing between April 1 and September 30, 2004 by Thunder Bay and Wawa area anglers, respectively. The pattern for the Wawa area anglers was less distinct than that for Thunder Bay anglers because of the differences in sample sizes (151 vs. 347 respondents). For both groups, fishing participation rates were very low until the weekend of May 15, 2004 – the opening of the walleye fishing season. Since almost 80% of anglers from these areas preferred to catch walleye (Hunt 2006), these large changes in angling participation rates were not surprising.

Angling participation rates were highest during the Victoria Day weekend (May 22-24, 2004), which signifies the beginning of summer to many northern Ontario residents[7]. Another interesting trend was the importance of



Source: Hunt (2006)

Figure 3. Daily fishing participation by Thunder Bay area anglers during summer 2004.

[7]Unlike most years, the walleye open water season did not coincide with the Victoria Day weekend in 2004.

weekend fishing – participation rates of Thunder Bay area anglers were highest on Saturdays and much lower on weekdays. Fishing participation rates declined after the Labour Day weekend (September 6, 2004) when children return to school. Apparently, culture and tradition are very strong determinants for understanding fishing participation decisions by Thunder Bay and Wawa area anglers.

The exact time of transition from ice to open water conditions varies for different water bodies. Rivers and streams are first to make this transition followed by large waters in the southern parts of the study areas. Finally, small waters that are shaded from direct sun may have ice cover into late April and early May. Little difference in angling participation rates exists during the transition of the ice and open water seasons (i.e., throughout April). Consequently, an earlier transition to open water fishing that does not involve changes to regulations for possessing fish such as walleye is unlikely to affect fishing participation rates. If this change in open water availability also involves changes that make walleye available to anglers earlier in the season, large changes in fishing participation rates by area anglers might occur.

Another interesting temporal trend from the diaries is the distribution of fishing effort on each fish species. To estimate these trends, we counted the number of fishing trips that occurred during each week of the fishing season. Next, we used information about the primary target fish species for each trip and converted these totals into percentages. We allocated all fishing trips to weeks based on the start date of the trip even when these trips extended into another week.

During the end of the ice fishing season (April 1 to April 14, 2004 for walleye), a large percentage of fishing trips targeted walleye. Second highest was brook trout, with greater importance in the Wawa than Thunder Bay area (see Figures 5 and 6). At the end of the walleye ice fishing season, active anglers from both areas focus on rainbow trout. These trout enter Lake Superior tributaries in April and May to spawn. The easy accessibility of many of these tributaries, along with poor road conditions and unsafe ice conditions on many inland lakes, leads to a strong preference by area anglers to target this fish species. Although the relative effort on rainbow trout is high between April 15 and May 15, overall participation rates in fishing are low during this time.

At the start of the walleye open water season (May 15, 2004) most fishing trips targeted walleye. These walleye trips continued to dominate through September 30, 2004 although there was some decline in effort on walleye later in the season. Salmon species received increased effort July through September. These species, which are available in Lake Superior, are preferred later in the summer and early fall.

Information on participation rates and targeted fish species revealed the importance of walleye to anglers. As such, any climatic change that affects the availability or quality of walleye fishing is likely to have dramatic effects on northern Ontario resident anglers. Some initially positive changes to walleye populations may lead to short-term benefits to anglers who will likely exploit these fish stocks. Whether the net effect of increased walleye productivity and angler exploitation would provide benefits or costs to present and future anglers is unclear.

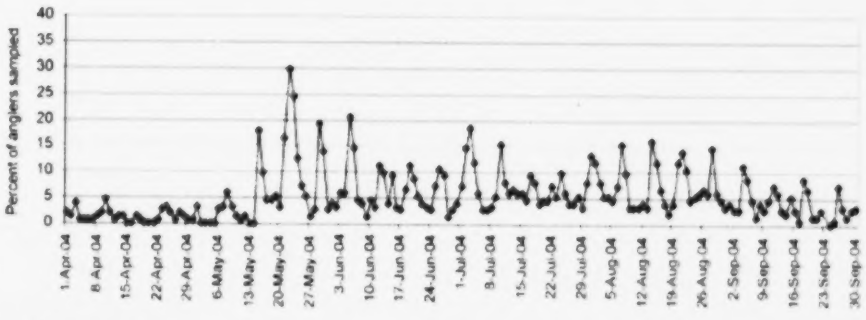
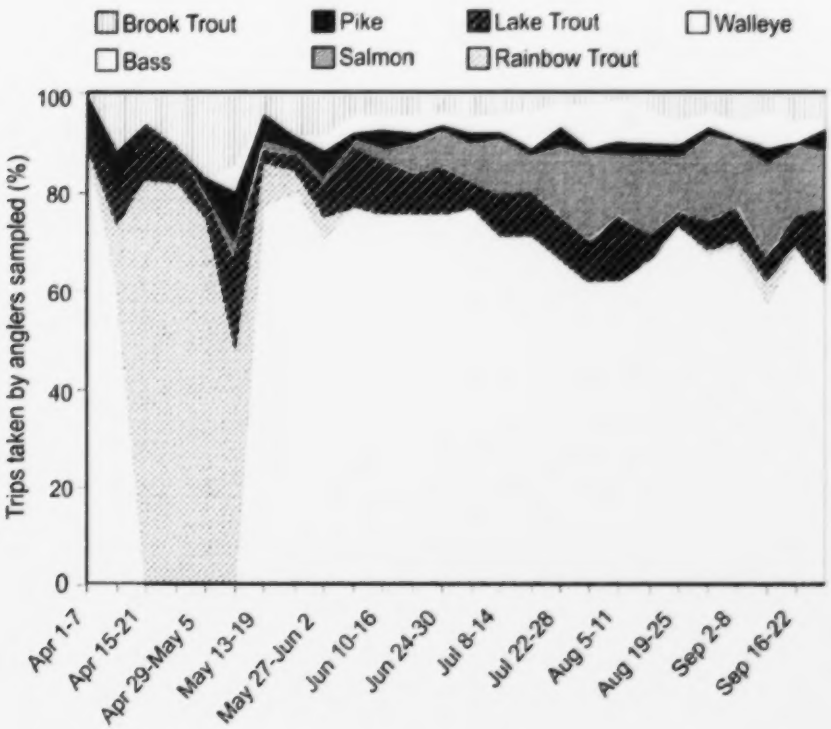


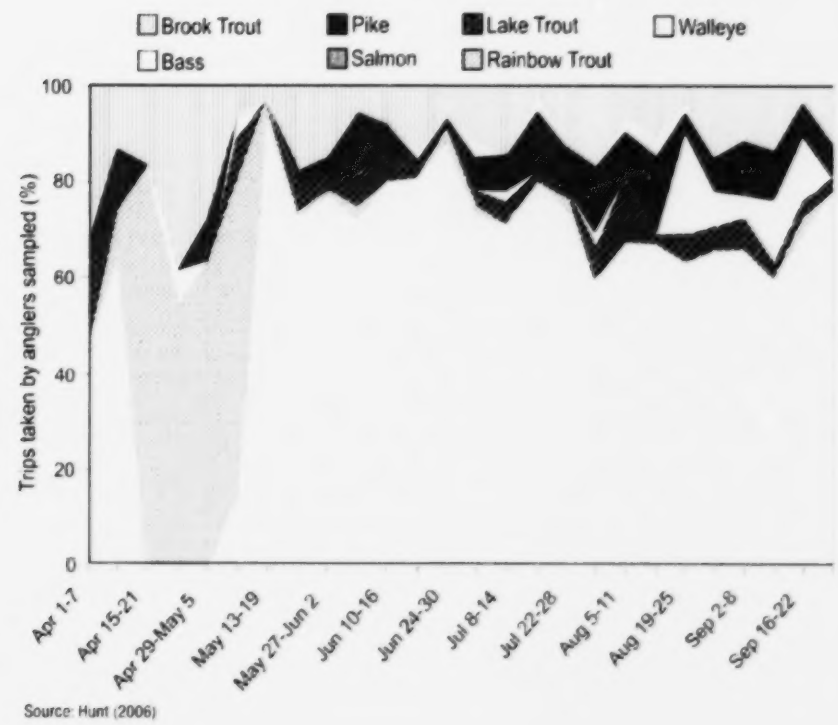
Figure 4. Daily fishing participation by Wawa area anglers during summer 2004.

Source: Hunt (2006)



Source: Hunt (2006)

Figure 5.
Percent of trips for each primary target fish species by week during summer 2004 in Thunder Bay study area.



Source: Hunt (2006)

Figure 6.
Percent of trips for each primary target fish species by week during summer 2004 in Wawa study area.

4.2. Weather and associations with angling effort

Anecdotal information from anglers, including many comments in the diaries, suggested that weather conditions during 2004, particularly during the spring, were less than ideal for angling. Many anglers commented that they did not fish as often as they desired due to the cold, wet conditions. Comparisons between the 2004 weather data and the 1971-2000 normals for Thunder Bay and Wawa revealed that temperatures were below normal for most of the summer (see Figures 7 and 8). In Wawa, April, May, and August were wetter than normal. September was the exception, with temperatures well above normal values and lower than normal precipitation. The potentially more desirable fishing opportunities in September seemed to be offset by culture and tradition that dictate that summer ends on the Labour Day weekend (September 4-6, 2004).

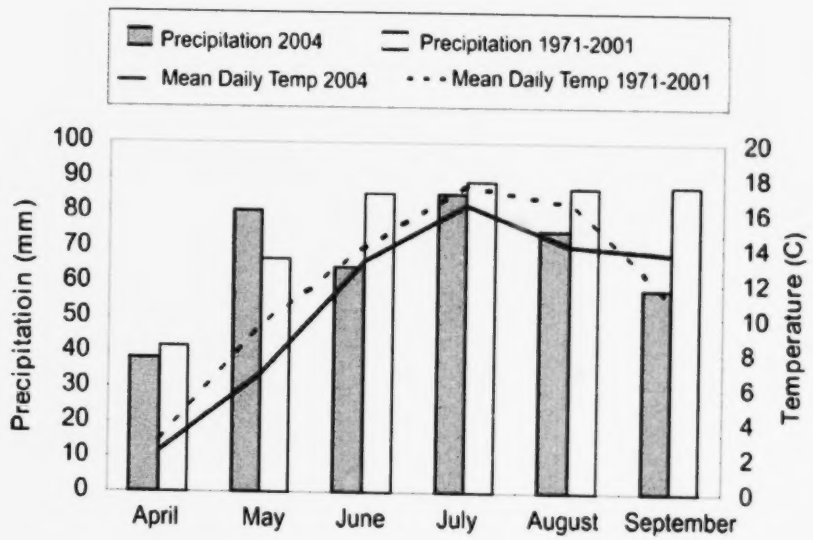


Figure 7. Thunder Bay weather attributes in 2004 compared to 1971-2000 average.

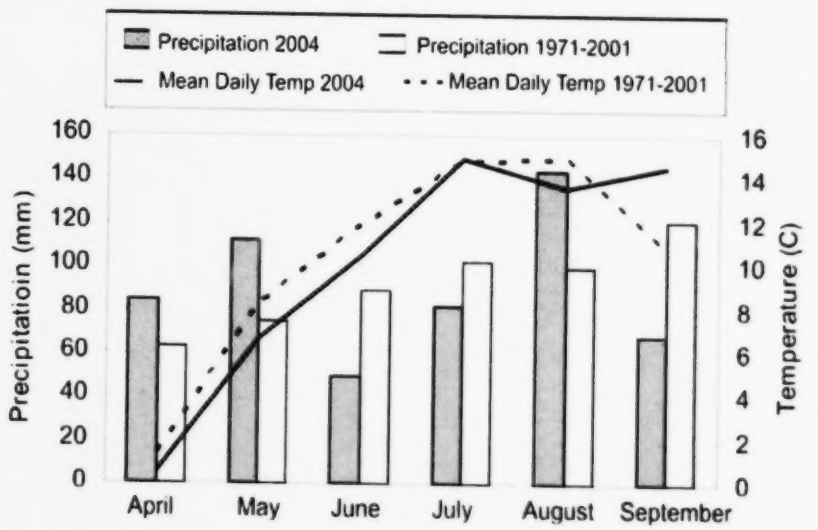


Figure 8. Wawa weather attributes in 2004 compared to 1971-2000 average.

4.3. Actual versus forecast weather

Actual weather conditions on a given day are not always correctly forecasted. As shown in Figure 9 however, a very strong positive correlation exists between actual and forecast temperatures (correlation coefficient = 0.929). Given the high correlation between forecast and realized weather and the better explanatory power of realized weather in the participation choice models, we employed the realized weather for all subsequent models[8]. This approach also eliminates the assumption that the Environment Canada weather forecasts used in the model were the same ones used by individual anglers in making their participation decisions about fishing on a given day.

4.4. Repeated nested logit models

We conceptualized the decision to participate in recreational fishing as involving two important periods (see Figure 10). First, we assumed that anglers plan their multiple-day fishing trips at the start of the fishing year. Second, during the fishing year, anglers decide on a near daily basis as to whether or not they will take a day-fishing trip. Within these periods, anglers decide about the types of fishing trips and locations for the trips. As described in Section 3, we separated trips into types that were included for the site choice models and other types (e.g., to sites with private accommodation).

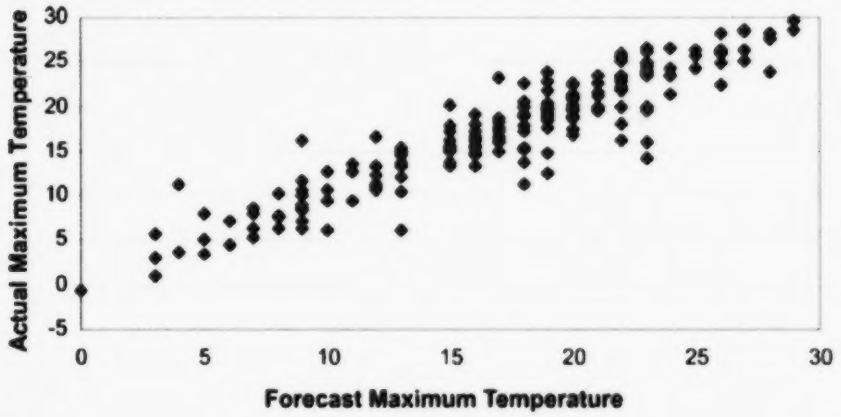


Figure 9. Actual vs. forecast maximum temperatures for Thunder Bay, April 1 through September 30, 2004.

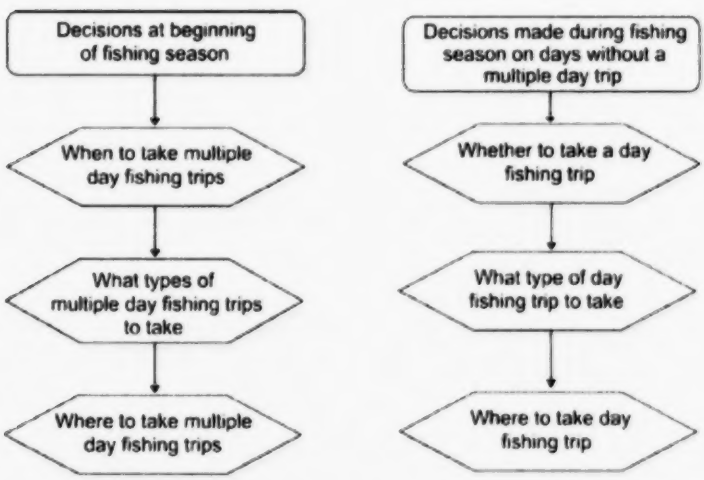

Decisions at beginning of fishing season
When to take multiple day fishing trips
What types of multiple day fishing trips to take
Where to take multiple day fishing trips
Decisions made during fishing season on days without a multiple day trip
Whether to take a day fishing trip
What type of day fishing trip to take
Where to take day fishing trip

Figure 10. Conceptual model for predicting fishing participation and site choice.

[8]The results of these models are available by request from the authors.

We used five separate models to estimate the joint decisions of fishing participation and site choice shown in Figure 10. First, we predicted the probabilities that anglers would choose multiple-day fishing trips. From the remaining days without multiple-day fishing trips, we estimated participation in day trips from a second participation model. Separate choice models were used to estimate the probabilities that anglers would select a fishing site for the Wawa and Thunder Bay areas, respectively. Finally, we used a model to estimate the expected catch rate for walleye for each angler and each fishing site.

While realized or expected temperatures may influence multiple and daily decisions to participate in fishing, rain and other precipitation are more likely to affect single-day than multiple-day fishing trips. However, our data consist of only one year of fishing trip data and it is difficult to assess the importance of daily weather events on fishing participation without multiple year data. For example, we know from Figures 3 and 4 that many fishing trips occurred on the Victoria Day weekend in May. Given that the expected temperatures for this weekend are much lower than for June, July, and August days, it is possible to conclude incorrectly that temperature is negatively associated with fishing effort. In reality, the negative sign on temperature reflects its correlation to the culture and tradition of fishing on the Victoria Day long weekend. As well, no efforts were made to relate the various weather data to site choices. For example, the fact that high wind speeds may direct anglers away from large towards smaller lakes was not investigated.

4.4.1: Expected walleye catch

The model in Table 2 was based on the reported walleye catch rates by both Thunder Bay and Wawa area anglers. This pooled Thunder Bay and Wawa data provided a large number of observations (1,783) from which to estimate the importance of various attributes. We found no differences in the effects of attributes on walleye catch rates with the exception that expected catch rates were generally higher for Wawa than Thunder Bay area lakes (*Area*).

Larger water bodies were more likely to produce higher walleye catch rates than smaller ones. Waters with lake trout or smallmouth bass (*Micropterus dolomieu*) had lower walleye catch rates than those without these species. Lake trout presence was negatively associated with walleye catch rates since lake trout are typically present in deep lakes that have clear waters. Therefore, the significant negative effect of lake trout presence on walleye catch rates acts as a proxy for attributes related to water clarity and water depth. Indeed, exploratory analyses of walleye catch rates on lakes where more detailed information was available indicated that walleye are more abundant in waters that are shallow and murky, and that these waters seldom support lake trout populations. Two reasons are hypothesized for the lower walleye catch rates associated with the presence of smallmouth bass. First, smallmouth bass may compete for the same baitfish as walleye. Second, anglers may introduce smallmouth bass into lakes where walleye fishing is poor.

The separation of an angler from the fishing site was also an important determinant of walleye catch rates. The further a waterbody was located from the community of interest (e.g., Thunder Bay), the higher the predicted catch rate for walleye. As well, waters that were accessible via a 500 m or longer trail[9] had higher walleye catch rates than did more easily accessible waters. All else considered equal, walleye catch rates were higher around Wawa than Thunder Bay.

Many characteristics of anglers or their equipment also helped to explain the reported walleye catch rates. First, anglers who were motivated to test equipment or to achieve relaxation reported higher walleye catch rates than did other anglers[10]. Second, the age of the angler had a non-linear association with reported walleye catch rates. Finally, if an angler owned a four-wheel drive vehicle, reported catch rates were higher.

Two attributes specific to the fishing trip were also important. First, anglers who fished from a boat were more likely to report higher walleye catch rates than were other anglers. Second, walleye catch rates were higher for anglers who stated that walleye was the primary rather than secondary fish species that they targeted.

[9]These trails included those accessible by walking or ATV.
[10]Motivations were determined from analyses of diary responses. Results of this analysis are found in Hunt (in prep.).

Table 2. Expected walleye catch rate model parameters and error rates for northern Ontario.

Variable	Parameter Estimate	Standard Error	t-value	Probability
Intercept	-3.73086	-1.60713	2.32	0.01
Travel distance from community (km)	0.00281	-0.00078	-3.63	<0.01
Accessible via 500 m or more ATV or walking trail	1.29441	-0.22956	-5.64	<0.01
Water area (ha)	0.00003	-0.00001	-4.50	<0.01
Presence of lake trout	-0.20574	-0.09157	2.25	0.01
Presence of smallmouth bass	-0.32951	-0.10034	3.28	<0.01
Primary or secondary targeted species	0.64592	-0.18765	-3.44	<0.01
Fished from boat	0.74499	-0.13947	-5.34	<0.01
Motivated to test equipment	0.12964	-0.03765	-3.44	<0.01
Motivated to relax	0.18666	-0.03763	-4.96	<0.01
Age	-0.07336	-0.03478	2.11	0.02
Age (square root)	0.92576	-0.47156	-1.96	0.02
Own a four-wheel drive vehicle	0.48343	-0.08674	-5.57	<0.01
Area (Thunder Bay +1, Wawa -1)	-0.25446	-0.05840	4.36	<0.01
Intercept for Garden Lake	1.30405	-0.46896	-2.78	<0.01
Intercept for Bedivere Lake	0.79712	-0.34862	-2.29	0.01
Intercept for Dog River	0.60068	-0.23184	-2.59	<0.01
Intercept for Poshkokagan and Cheeseman Lakes	0.62590	-0.25680	-2.44	0.01
Intercept for Nelson, Swallow, and Batwing Lakes	0.71123	-0.20453	-3.48	<0.01
Intercept for Kagiano Lake	1.16737	-0.42830	-2.73	<0.01
Sigma	1.44867	-0.02742	-52.84	<0.01

Source: Hunt (2006)

4.4.2 Fishing site choice models

Fishing site choice models were estimated separately for Wawa and Thunder Bay area respondents. The models included several attributes (see Table 3) including one that captured spatial association among proximal sites *(DS_ALL)*[11]. If this parameter estimate equals one, relative changes in use of fishing sites are identical. This statement implies that the closure of a fishing site that had 50% of all angling effort would result in a doubling of effort at all other neighbouring fishing sites. If the parameter estimate was less than one, fishing sites near the closed site would receive more than a doubling of fishing effort while other more distant sites would receive less than a doubling of effort. Put differently, nearby sites act as better substitute fishing sites than do more distant sites when this *DS_ALL* parameter estimate is significantly less than one.

[11] Technically, to be consistent with random utility theory, this dissimilarity parameter should range from zero to one (Daly and Zachary 1978, McFadden 1981). One minus the dissimilarity parameter provides a crude indicator of the correlation among the unobserved utility of alternatives within nests (Train 2003). Each Thunder Bay area fishing alternative was allocated to eight nests based on the inverse distance between the site and the nest divided by the total inverse distances of the site to all nests. Five such nests were used for alternatives from the Wawa area. As such, each alternative was cross-nested into all of the nests through this allocation procedure.

Table 3. Description of attributes included in the fishing site choice models.

Label	Description
DS_ALL	Dissimilarity parameter estimate for all nests
OUTSIDE	Trips taken outside of study area (1, 0)
UNKOWN	Trips taken to unknown locations within the study area (1, 0)
ASC_YYY	Alternative specific constant for fishing alternative YYY
A_WALL	Availability of walleye (0, 1)
A_BASS	Availability of smallmouth bass (0, 1)
A_LTROUT	Availability of lake trout (0, 1)
A_BTROUT	Availability of brook trout (0, 1)
A_BSTR	Availability of smallmouth bass and any type of trout species (0,1)
A_ERRT	Availability of spring rainbow trout in Lake Superior tributaries (Wawa only) (0,1)
E(W_CUE)	Estimated walleye catch rate per one hour of fishing
RT_CUE	Average reported rainbow trout catch rate per one hour of fishing (Thunder Bay only)
LN_WAREA	Natural logarithm of area of fishing waters (ha)
T_DIST	Travel distance from origin to destination waters (km)
R_PAVE	Travel distance along a paved road (fixed to zero for identification purposes (km))
R_HQGR	Travel distance along a high quality gravel road (km)
R_MQGR	Travel distance along a mid quality gravel road (km)
R_PQGR	Travel distance along a poor quality gravel road (km)
R_TRAIL	Travel distance along a trail (km)
PORTAGE	Whether or not fishing alternative is accessed by a popular portage trail (0,1)
BT*GDLN	Presence of a good boat launch (0,1) times whether trip was taken from boat (1, -1)
BT*NOLN	Presence of no boat launch (0,1) times whether trip was taken from boat (1, -1)
COTTAGE	Presence of significant cottage development (Thunder Bay)
LN_UNAC	Natural logarithm of unique access points
W*XXX	Interaction between attribute XXX and whether the angler fished during the winter (1, -1)
MD*XXX	Interaction between attribute XXX and whether the trip was a multiple or day trip (1, -1)

Table 4 provides summary statistics for the attributes described in Table 3. The site choice models are based on information about travel distances, fishing quality, boat launches, cottage development, water surface area, number of access points, and the described measure of spatial similarity among the alternatives.

Travel distances were determined for each angler origin and fishing site through automated GIS network analyses based on minimizing travel time. Average travel distances from points of origin to fishing sites were slightly greater in the Thunder Bay area (124.2 km) compared to the Wawa (108.4 km) area.

Results from the qualitative interviews with northern Ontario anglers suggested that the quality of roads and trails leading to fishing sites would heavily influence the use of those sites by some anglers. Therefore, we included distance measures for paved roads (*R_PAVE*), high quality gravel roads (*R_HQGR*), mid quality gravel roads (*R_MQGR*), poor quality gravel roads (*R_PQGR*), and trails (*R_TRAIL*) in the choice model. High quality

gravel roads included all two-lane gravel roads that were well maintained. Mid-quality gravel roads included two-lane gravel roads with maintenance problems and well maintained single-lane gravel roads. Maintenance problems were identified by field staff and include vegetation overgrowth, severe pot holes, washed out sections of the road, and deterioration of the gravel substrate. Poor quality gravel roads were one-lane roads with some type of maintenance problem. Visits by field staff in either the summers of 2003 or 2004 were used to estimate road maintenance. Average travel distances along these different types of roads and trails varied markedly. While most sites involved very little travel on trails or poor quality gravel roads, average distances along paved and high quality gravel roads were much greater. Areas accessible by popular portages comprised a small percentage of fishing sites in the two study areas (see Table 4).

Three types of fishing quality information were used for the site choice models. The availability of fish species in a given waterbody was determined by whether the species was present and legal to catch and possess at the time of the angling trip. Walleye were present in a majority of the fishing sites in the Wawa and Thunder Bay areas followed by brook trout. Lake trout was next most often found, while smallmouth bass were found less often in Thunder Bay fishing sites and almost never in Wawa area fishing sites.

Catch rates for rainbow trout in the Thunder Bay area were based on reported catches by diary respondents and were separated by timing and geography. This spatio-temporal attribute was required since rainbow trout leave Lake Superior in the early spring via the more southerly tributaries and end up in the most northerly tributaries by late spring.

Table 4. Attribute summary measures based on fishing alternatives

	Thunder Bay		Wawa	
Label	Mean	Std. Dev.	Mean	Std. Dev.
T_DIST	124.2 km	56.4 km	108.4 km	58.9 km
R_PAVE	99.1 km	47.2 km	87.3 km	54.3 km
R_HQGR	20.4 km	24.0 km	14.2 km	19.6 km
R_MQGR	2.9 km	6.6 km	2.0 km	4.6 km
R_PQGR	1.5 km	3.3 km	0.7 km	1.9 km
R_TRAIL	0.4 km	1.5 km	0.6 km	2.0 km
PORTAGE	6.1 %	NA	0.7%	NA
A_WALL*	53.1 %	NA	60.5%	NA
A_BASS*	17.0 %	NA	3.0%	NA
A_LTROUT*	17.5 %	NA	14.0%	NA
A_BTROUT*	21.9 %	NA	28.0%	NA
A_BSTR*	6.1 %	NA	1.2%	NA
LN_WAREA+	1270.2 ha	15695.7 ha	251.8 ha	68.6 ha
GDLN	42.2 %	NA	46.0%	NA
NOLN	19.6 %	NA	15.3%	NA
COTTAGE	3.5 %	NA	NA	NA
LN_UNAC+	1.4	1.7	1.2	0.8

' see Table 3 for label descriptions
* based on the presence and not availability of the fish species
+ measured by logarithm

Since almost 80% of the Wawa and Thunder Bay area anglers contacted by phone stated that they preferred to catch walleye, we decided to model the expected catch of walleye for each water body and each trip (see Table 2). Details on estimating the expected catch rate of walleye for each angler and each fishing alternative are provided in Appendix 1.

Given the wide variety of boat launch types, we created groups of no boat launches (*NOLN*), good boat launches (*GDLN*), and other boat launches. Good boat launches consisted of concrete, gravel, or sand. Other boat launches included landings with rocks, grass and/or other materials and were found at over 40% of fishing sites in the two study areas. Cottage development was used as a proxy for congestion at the waters. This attribute, which was populated through expert judgment, accounted for only 3.5% of Thunder Bay fishing sites. Finally, some alternative specific constants were used to account for trips outside the study areas, to unknown locations, to Lake Superior and to a few other waters that were poorly predicted by the site choice model.

We accounted for angler heterogeneity in preferences in a simple way. We separated anglers based on whether or not they reported fishing during the ice season in 2003. We investigated whether these different market segments had different preferences for the site attributes (*W**). To account for potential differences in preferences for day and multiple-day trips, we used this same market segmentation approach for day and multiple-day trip contexts (*MD**). Finally, we combined the boat launch types with whether an angler fished or did not fish from a boat (*BT**).

Not all attributes from Table 3 were included in both site choice models. Because of a small sample size of anglers from the Wawa area who reported catch information on rainbow trout, we used an indicator of rainbow trout presence in tributaries (*A_ERRT*) rather than reported catch (*RT_CUE*). As well, the cottage development attribute (*COTTAGE*) was only included through an alternative specific constant for Wawa Lake in the Wawa area. Finally, the expected walleye catch (*E(W_CUE)*) for the Wawa area site choice models was not included since it yielded counter-intuitive results[12].

Although the site choice models were estimated separately for the Thunder Bay and Wawa area anglers, for the sake of parsimony, we included all of the estimates in Table 5. Appendix 1 provides details about how one may use the information from Table 5 to estimate the probability that anglers will select a fishing alternative. Parameter estimates cannot be compared directly between the two models as they are based on interval and not ratio scales (i.e., the parameter estimates may have different levels of variability). For the sake of comparison, we include asymptotic t-values that represent a slightly better method for comparing the model results. Even this t-value comparison requires caution since the Thunder Bay model was based on more trip data than the Wawa model; therefore, the t-values for the Thunder Bay parameter estimates should be larger.

The two models are similar in many ways. The parameter estimates are more often significantly different from zero for the Thunder Bay than the Wawa area model due to the larger number of modelled trips for Thunder Bay (1152) than Wawa (749). Both models fit the data reasonably well with adjusted ρ^2 values of 0.268 and 0.325[13], respectively. In both models, the likelihood of selecting a fishing site increases with decreasing travel distance (*T_DIST*), increasing availability of desirable fish species (e.g., *A_WALL*), increasing water areas (*LN_WAREA*), increasing number of access points (*LN_UNACC*), and the presence of boat launch facilities (e.g., the negative value for *BT*NOLN*). For Thunder Bay area anglers, fishing sites were also attractive if they had higher catch rates for walleye (*E(W_CUE)*) and rainbow trout (*RT_CUE*) and did not have extensive cottage development (*COTTAGE*). Waters that were accessible only by trails (*R_TRAIL*) acted as a deterrent to anglers, especially anglers who did not fish during the previous winter (*R_W*TRAIL*). A similar dynamic was found for the poor quality access roads (*R_PQGR* and *W*R_PQGR*) for the Thunder Bay but not the Wawa area anglers.

Only a few differences were found among the importance of attributes for day and multiple-day trips. Anglers who were taking multiple-day trips were more likely to choose fishing sites outside the study area (*MD*OUTSIDE*).

[12] We believe that this finding is spurious as most anglers from the Wawa area stated that they preferred to catch walleye.
[13] An adjusted ρ2 value between 0.200 and 0.400 represents a good fit with the data.

Table 5. Site choice model results for Thunder Bay and Wawa areas.

	Thunder Bay		Wawa	
Label	Parameter Estimate	t-value	Parameter Estimate	t-value
DS_ALL	0.7601 ***	18.94	0.5962 ***	13.39
OUTSIDE	2.9294 ***	6.85	0.5669	1.52
MD*OUTSIDE	2.4312 ***	9.89	0.9801 ***	3.67
UNKNOWN	2.8886 ***	6.87	1.2782 ***	3.72
MD*UNKNOWN	1.1429 ***	4.92	0.5162 **	2.31
ASC_LK_SUP	1.6642 ***	5.12	1.2126 ***	4.37
ASC_LK_NIP	2.0755 ***	5.83	NA	
ASC_KAM RIV	-0.5317 ***	-3.73	NA	
ASC_DOG_LAKE	-0.6798 ***	-4.08	NA	
ASC_DOG RIV	0.2157	0.74	NA	
MD*ASC_DOG RIV	-0.8914 ***	-3.13	NA	
ASC_WAWA	NA	NA	-0.7718 ***	-4.56
ASC_MGPIE	NA	NA	0.1621	1.22
A_WALL	0.5280 **	2.80	0.6446 ***	4.68
MD*A_WALL	-0.4585 ***	-3.04	0.0451	0.40
A_BASS	0.5169 ***	5.12	0.2140	1.07
MD*A_BASS	0.3007 ***	4.06	-0.3405 *	-1.83
A_LTROUT	0.6982 ***	6.74	0.2005 **	2.43
A_BTROUT	1.0298 ***	6.96	0.1175	1.45
A_BSTR	-0.4733 ***	-3.95	-0.1496	-0.84
A_ERRT	NA	NA	0.7702 ***	3.50
W*A_ERRT	NA	NA	-0.3603 *	-1.78
E(W_CUE)	0.9410 ***	7.02	NA	NA
W*E(W_CUE)	-0.2124 ***	-4.51	NA	NA
MD*E(W_CUE)	0.4441 ***	4.13	NA	NA
RT_CUE	3.1403 ***	11.31	NA	NA
W*RT_CUE	-0.5620 ***	-3.34	NA	NA
LN_WAREA	0.2170 ***	7.42	0.2028 ***	8.23
T_DIST	-0.0127 ***	-11.08	-0.0249 ***	-13.58
MD*T_DIST	0.0075 ***	10.43	0.0049 ***	3.90
R_HQGR	-0.0029	-1.52	0.0096 ***	5.76
R_MQGR	0.0003	0.04	0.0505 ***	6.92
R_PQGR	-0.0171	-1.33	0.0154	0.88
W*R_PQGR	0.0363 ***	2.97	-0.0213	-1.28
R_TRAIL	-1.2808 ***	-4.81	-0.0509 *	-1.80
W*R_TRAIL	1.2149 ***	4.64	0.0288	1.07
PORTAGE	-1.0160 **	-2.60	-0.3872	-0.92
BT*GDLN	0.5146 ***	6.91	-0.1429 **	-2.78
BT*NOLN	-0.6142 ***	-4.88	-0.4918 ***	-3.72
COTTAGE	-1.0802 ***	-5.88	NA	NA
W*COTTAGE	-0.5714 ***	-3.50	NA	NA
LN_UNAC	0.4306 ***	5.13	0.2810 ***	3.23
Log likelihood (chance; β=0)	-6988.2		-4339.0	
Log likelihood (model)	-5080.2		-2899.1	
Adjusted ρ^2	0.268		0.325	

*** p<0.01 ** p<0.05 * p<0.10

* see Table 3 for label descriptions

to unknown locations (*MD*UNKNOWN*), and to further away sites (*MD*T_DIST*). For Thunder Bay, those anglers taking multiple-day trips placed less importance on walleye availability (*MD*A_WALL*), more importance on walleye catch rates (*MD*E(W_CUE)*), and more importance on waters with smallmouth bass (*MD*A_BASS*).

Only a few differences in preferences for the attributes were found between anglers who did and did not fish during the winter of 2003. Besides the already explained difference in roads and trails, Thunder Bay anglers who fished during the previous winter were less influenced by walleye (*W*E(W_CUE)*) and rainbow trout catch rates (*W*RT_CUE*) and the presence of extensive cottage development (*W*COTTAGE*) than were anglers who did not fish during the previous winter. Wawa area anglers who fished during the previous winter placed less importance on the availability of rainbow trout during the spring season (*W*A_ERRT*) than did their counterparts.

4.4.3. Participation modelling

The site choice models for the Thunder Bay and Wawa areas were used to estimate the expected maximum utility of fishing alternatives for day and multiple-day trips for each angler (see Appendix 1 for details). This estimated value was included in the participation site choice models to link trip frequency changes to fishing site changes (e.g., changes to expected catch rates at some lakes). While this sequential estimation results in inefficient standard errors for the participation models (Train 2003), a full information maximum likelihood model was not feasible due to computer memory limitations. Thus, reported probabilities of parameter estimates being zero in the participation model are likely lower than actual values (i.e., there is an overestimation of the reported t-values).

We estimated the participation choice model for multiple-day trips with information about the expected maximum utility from the site choice models. Three alternatives were present in each of the participation models. For the multiple-day trip model, the alternatives were: do not take a multiple-day trip; take a multiple-day trip with a context used in the site choice (modelled multiple-day trip); and take a multiple-day trip of a different context (other multiple-day trip). Given our assumption about participation behaviours, we removed all days with multiple-day trips from the day trip model (see Figure 10). As such, an angler's day trip participation depends not only on the day participation model but also the results of the multiple day participation model. The alternatives for the day trip were: do not participate in fishing; participate in a trip context that was used to estimate the site choice model (modelled day trip); and participate in a trip with a different context (other day trip).

Data were pooled for both the Thunder Bay and Wawa area respondents and significant differences among the factors for these two populations were retained in the model. The attributes included in the model and their mean values are shown in Table 6. These attributes focus on themes of calendar, angler characteristics, weather, and expected maximum utility of fishing alternatives. Calendar information included indicators of whether the trip occurred on a Friday, Saturday, Sunday, holiday weekend, before walleye season (before May 15, 2004) (*PWALLEYE*), or after Labour Day weekend (after September 6, 2004) (*SEPT*). Angler characteristics included whether or not the angler owned a cottage, all terrain vehicle (*ATV*), truck, or boat and the number of years that an angler fished (*YRS*). Weather information was based on realized weather conditions of maximum temperature (*TEMP*) and proportion of day (6:00AM to 9:00PM) with rain or precipitation (*RAIN*). Other weather attributes related to wind speed and proportion of the day with cloud cover were excluded since they were not significant in any of the participation models.[14] Finally, the expected maximum utilities were estimated (*IV_THBAY* and *IV_WAWA*) for each angler and each fishing day and were included as attributes in the participation models.

Two different types of interactions were included in the participation models. First, we assessed the importance of the various attributes on site choice modelled and other trip alternatives in the models (*MOD**). Significant interactions would provide evidence that the attribute had a different effect on the decision to participate in a site

[14]Results from these models are available from the authors by request.

Table 6. Attributes for fishing participation choice models

Label	Description	Thunder Bay (Mean)	Wawa (Mean)
PART	Participate	NA	NA
FRIDAY	Friday participation	14.3%	14.3%
SATURDAY	Saturday participation	14.3%	14.3%
SUNDAY	Sunday participation	14.3%	14.3%
HOLIDAY	Holiday weekend participation	8.5%	8.5%
MAYLONG	Participation during Victoria Day long weekend	2.0%	2.0%
PWALLEYE	Participation before walleye season	8.5%	8.5%
SEPT	Participation after Labour Day weekend	15.7%	15.7%
TEMP	Participation * maximum recorded temperature (C)	18.9	16.9
RAIN	Participation * proportion of day with precipitation	0.09	0.10
COTTAGE	Participation by cottage owners	31.1%	54.3%
ATV	Participation by ATV owners	28.8%	46.4%
TRUCK	Participation by truck owners	63.7%	78.1%
BOAT	Participation by boat owners	83.3%	90.7%
YRS	Participation * years fished	34.0	28.1
IV_WAWA	Expected maximum site attractiveness for Wawa	NA	NA
IV_THBAY	Expected maximum site attractiveness for Thunder Bay	NA	NA
DUBREUIL	Participation by Dubreuilville residents	NA	39.1%
MANITOU	Participation by Manitouwadge residents	NA	15.9%
MOD*XXX	Modelled trip alternative * attribute XXX	NA	NA
T*XXX	Residence (1 Thunder Bay, -1 Wawa) * attribute XXX	NA	NA

choice modelled rather than other type of trip. Second, we combined the effect of residence (i.e., Thunder Bay or Wawa area) with the various attributes (*T**). Any significant interactions suggest that the attribute had a different effect on the decision to participate in fishing by Thunder Bay and Wawa area anglers. For all participation models, interactions were included if they or other interactions based on the attributes were significantly different from zero.

Although the multiple-day and day participation models were estimated independently, they are both presented in Table 7. Appendix 1 describes the process for using these estimates to predict fishing participation probabilities. Again, the parameter estimates from the two models are not directly comparable. One may, however, use the t-values to compare the relative importance of the attributes between the day and multiple-day models.

The models fit the data very well. For the Wawa and Thunder Bay multiple-day and day fishing participation decisions the adjusted ρ^2 values are 0.84 and 0.88, respectively. While this great model fit arises from the fact that most anglers do not participate in fishing on any given day (i.e., the large negative values for *PART*), many of the remaining attributes are highly significant in both models.

Table 7. Participation choice models for multiple day and day trips.

Label*	Multiple Day Parameter Estimate	Standard Error	Day Parameter Estimate	Standard Error
PART	-7.3991 ***	-33.53	-6.9475 ***	-29.40
MOD*PART	-0.5481	-0.54	1.2960 **	1.98
FRIDAY	1.0106 ***	15.93	0.4509 ***	3.34
MOD*FRIDAY	-0.2407 **	-2.27	-0.4790 ***	-3.06
SATURDAY	1.2580 ***	24.90	1.2291 ***	21.72
SUNDAY	1.1212 ***	21.56	0.5499 ***	8.15
HOLIDAY	0.5248 ***	6.50	0.1550 *	1.92
MOD*HOLIDAY	-0.1307	-1.12	NS	NS
MAYLONG	0.8746 ***	9.36	0.8188 ***	6.46
PWALLEYE	-1.9414 ***	-10.26	-1.1441 ***	-8.14
SEPT	-0.5825 ***	-5.66	-0.3348 ***	-4.37
TEMP	0.1723 ***	3.41	-0.1256 **	-2.29
MOD*TEMP	-0.3532 ***	-4.35	NS	NS
RAIN	NA	NA	-0.7964 ***	-5.22
COTTAGE	1.2040 ***	16.52	1.8278 ***	9.94
MOD*COTTAGE	-1.4778 ***	-16.07	-2.3101 ***	-12.09
ATV	-0.2691 ***	-4.63	-0.0653	-0.56
MOD*ATV	0.4343 ***	5.26	0.0736	0.57
TRUCK	0.6351 ***	7.60	-0.0766	-1.40
BOAT	1.3158 ***	7.83	0.2718 ***	3.30
YRS	0.6421 ***	3.77	0.3668	0.84
MOD*YRS	-0.5883 *	-1.99	1.6938 ***	3.59
IV_WAWA	0.3484 **	2.52	0.4542 ***	3.08
IV_THBAY	0.2189 ***	5.70	0.2068 ***	6.67
DUBREUIL	0.5888 ***	3.98	NA	NA
MANITOU	NA	NA	0.4684 ***	3.89
T*PART	1.1988 ***	6.40	NS	NS
T*HOL	0.0617	0.83	NS	NS
T*MOD*HOLIDAY	-0.4189 ***	-3.60	NS	NS
T*PWALLEYE	-0.6269 ***	-3.43	NS	NS
T*SEPT	-0.2132 **	-2.07	NS	NS
T*COTTAGE	-0.1580 **	-2.74	-0.6050 ***	-4.01
T*MOD*COTTAGE	NS	NS	0.5232 ***	3.29
T*ATV	0.1587 ***	3.14	-0.1570	-1.35
T*MOD*ATV	NS	NS	0.3050 **	2.39
T*TRUCK	-0.4802 ***	-5.74	0.1299 **	2.40
T*BOAT	-0.3652 **	-2.17	0.3455 ***	4.05
T*YRS	NS	NS	1.0337 **	2.65
T*MOD*YRS	NS	NS	-2.3567 ***	-5.46
Log likelihood (chance; β=0)	-84597.5		80270.1	
Log likelihood (model)	-13315.0		-9521.8	
Adjusted ρ^2	0.8384		0.8810	

* see Table 4.5 for label descriptions

*** p<0.01 ** p<0.05 * p<0.10 NS – Not Significant

The models fit the data very well. For the Wawa and Thunder Bay multiple-day and day fishing participation decisions the adjusted ρ^2 values are 0.84 and 0.88, respectively. While this great model fit arises from the fact that most anglers do not participate in fishing on any given day (i.e., the large negative values for *PART*), many of the remaining attributes are highly significant in both models.

Thunder Bay area anglers were more likely to take a multiple-day fishing trip than were Wawa area anglers (*T*PART*). The day of the week was also very important to anglers with most preferring Fridays, Saturdays, Sundays, holiday weekend days, and the Victoria Day holiday weekend (*MAYLONG*). This preference for Fridays, Sundays, and holiday weekends appears to be greater for multiple than for day trip decisions. While anglers less preferred days before the walleye season (*PWALLEYE*) and after the Labour Day weekend (*SEPT*), these dates appear to have less effect on decisions of anglers to participate in day than in multiple-day trips.

The weather data provided some counter-intuitive results. For all day and modelled multiple-day trips, the maximum temperature (*TEMP* and *MOD*TEMP*) had a negative effect on participation. This suggests that anglers prefer to fish on cooler days. It is likely that the result arises from reliance on one year of fishing trip data. Given that anglers take many fishing trips in late May and early June as part of culture and tradition, the cooler weather during this period may have created the spurious finding that weather is negatively associated with participation. For day trips, days with a substantial proportion of rain (*RAIN*) reduced day fishing trip participation.

All parameters for the expected maximum utility (*IV_WAWA* and *IV_THBAY*) estimates ranged from zero to one and were significantly different from one. These findings make the models consistent with random utility theory and reject a multinomial model form (i.e., the fishing alternatives are not equal alternatives to the do not participate and other fishing trip alternatives). We had to include some measures of residency of anglers (*DUBREUIL* and *MANITOU*) to account for the different rates of participation for multiple and day trips among these residents. Until these residency measures were added, problems existed with the parameter estimates for the expected maximum utility (*IV_WAWA*) for Wawa area respondents.

The interactions among the residence and modelled trips complicate the discussion of the role of angler characteristics on participation decisions. Cottage owners were more likely to take other than a modelled fishing trip (*MOD*COTTAGE*). Truck owners from Wawa appeared to be more likely to take any multiple-day over a day trip (*TRUCK* and *T*TRUCK*). Boat owners were more likely to participate in any trip with the exception of day trips by Wawa area anglers. Wawa area anglers who took modelled fishing trips were likely to have fished for many years (*YRS*, *MOD*YRS*, *T*YRS*, and *T*MOD*YSR*). The relatively small sample size of Wawa area anglers along with the high degree of collinearity among some of these variables (e.g., almost all ATV owners also own a truck) creates some noise that masks some relationships between angling characteristics and participation decisions.

With the above participation and site choice models, one can estimate probabilities that an angler will select a fishing site on a given day for a day or multiple-day fishing trip (see Appendix 1 for details). Thus, one may construct a variety of scenarios including those related to climate change and assess the effects of such scenarios on the amount, timing, and location of angling effort. Given the models' consistency with random utility theory, how such scenarios affect the economic value of fishing to these resident northern Ontario anglers can be estimated.

5. Scenario Forecasts

We demonstrate the utility of the forecasting model through a modelled scenario involving the extirpation of lake trout from Thunder Bay area waters. While such a loss could result from climate change, **no claim is made that this scenario is a likely outcome from climate change**. The scenario is simply used to demonstrate the flexibility of the repeated nested logit model at forecasting changes to the amount, timing, and spatial pattern of northern Ontario resident fishing trips.

Before using the choice models to estimate the spatial and temporal changes in recreational fishing trips and the economic value of recreational fishing, we add some caveats. First, we only model a change to lake trout availability. If this scenario arose from climate change, changes to the abundance and availability of other coldwater and coolwater fish species would also likely occur. The redistribution of angling pressure among the waters would also likely affect the quality of other fishing sites. Second, we hold all weather data and calendar events (e.g., holidays) constant for the 2004 year. If climatic conditions led to the loss of lake trout, it is likely that future weather conditions would differ. Third, the estimated effects are conservative since we only modelled angling trip behaviours from May 1 to September 30.

Some assumptions were required to operationalize the model. First, we estimated the Thunder Bay angling population from the population greater than 15 years of age (Statistics Canada 2002) and the proportion of the population who fish (DuWors et al. 1999). These sources led to an estimate of 25,800 anglers for the Thunder Bay area. To account for differences in trip-taking behaviours among anglers, the angling population was separated into 160 unique groups (i.e., market segments). Anglers were separated by residence (five origins), ownership of all terrain vehicles, trucks, boats, and cottages, and whether or not they fished during the winter season. Estimates of the proportions of anglers with each of these characteristics are provided in Table 8.

Over 90% of Thunder Bay area anglers come from the city of Thunder Bay. Proportions of Thunder Bay area anglers who owned various equipment were obtained from the telephone survey used before the recruitment of anglers to the diary program. These survey responses suggest that most Thunder Bay area anglers own trucks and boats and over one-quarter of the anglers own all-terrain vehicles. The telephone survey responses also suggested that over one-third of these anglers had fished during the ice season in the previous year. Finally, responses to the angling diary suggested that over one-fifth of anglers own a cottage. For continuous variables such as age, years fished, and fishing motivations, the average value was used for all anglers.

Table 8. Estimated percentage of Thunder Bay area anglers by select characteristics.

Characteristic	Percentage
Residence[1]	
Thunder Bay	91.51
Kakabeka Falls	5.43
South Gillies	2.11
Nolalu	0.59
Dorion	0.36
Truck owners[2]	79.2
Boat owners[2]	82.5
All terrain vehicle owners[2]	27.6
Cottage owners[3]	21.4
Ice anglers[2]	35.9

1 – Source: Statistics Canada (2002)
2 – Source: Telephone survey with Thunder Bay anglers
3 – Source: Diary participant responses

A few more assumptions were used to estimate changes to the economic value of fishing. First, we converted travel distances into travel costs through a value of $1.09 per return km. This value comes from the average operating expenses for a Dodge Caravan in 2004 that an individual drove 18,000 km annually with fuel costs $0.744/litre (CAA 2004). To avoid double counting trips that occurred over multiple days, we assumed that all multiple-day fishing trips lasted three days. The estimated change to economic value simply involved the change to the expected maximum utility. Specifically, this estimate equalled the difference in expected maximum utility before and after the change (i.e., the logarithm of the denominator in equation 4 in

Appendix 1) divided by the distance parameter (*T_DIST* and *MD*T_DIST* from Table 5) multiplied by the $1.09 per return km value of travel.

The forecasted change to the economic value of day fishing trips from the lake trout extirpation scenario was a reduction of approximately $100,000 per year for Thunder Bay area anglers. An additional loss of about $80,000 per year would also occur for multiple day fishing trips. Therefore, a loss of lake trout fishing opportunities to Thunder Bay area anglers between May 1 and September 30 would result in a forecasted loss of about $175,000 per year in economic value. Put differently, Thunder Bay area anglers would be willing to pay $175,000 per year to avoid the loss of current lake trout fishing opportunities from May 1 to September 30.

Lake trout extirpation would also likely affect the number, timing, and locations of fishing trips taken by Thunder Bay area anglers from May 1 to September 30. The models predicted that daily fishing effort would decline by over 5,400 days resulting in a loss of 2.1% of fishing effort in the Thunder Bay area. This relative effect would be greatest for modelled day trips (3.8% loss) since many day fishing trips occur at Lake Superior.

Before the scenario, the models predicted a strong pattern of fishing trip timing and trip type behaviours (see Figure 11). While the model predicted that angling effort would be very low early in May, a large increase to angling effort would occur following the open water walleye season on May 15. Angling effort was predicted to peak on each weekend throughout the season with highest use during the Victoria Day holiday weekend in May. After Labour Day (September 5, 2004), the amount of expected angling effort declined.

Angling effort was expected to be greatest for modelled day fishing trips and lowest for other types of day trips (e.g., to private accommodation). Modelled and other multiple day (Mday) fishing trips were expected to be most prevalent during weekend days.

The model predicted that some changes in the timing of and number of trips would occur from the extirpation of lake trout. We report these expected changes in use as a relative change in total fishing effort for each day (see Figure 12). Almost no change in use was forecasted before May 22. During this time, only a few waters would have been available for anglers to catch and possess lake trout in the study area. On May 22, the open

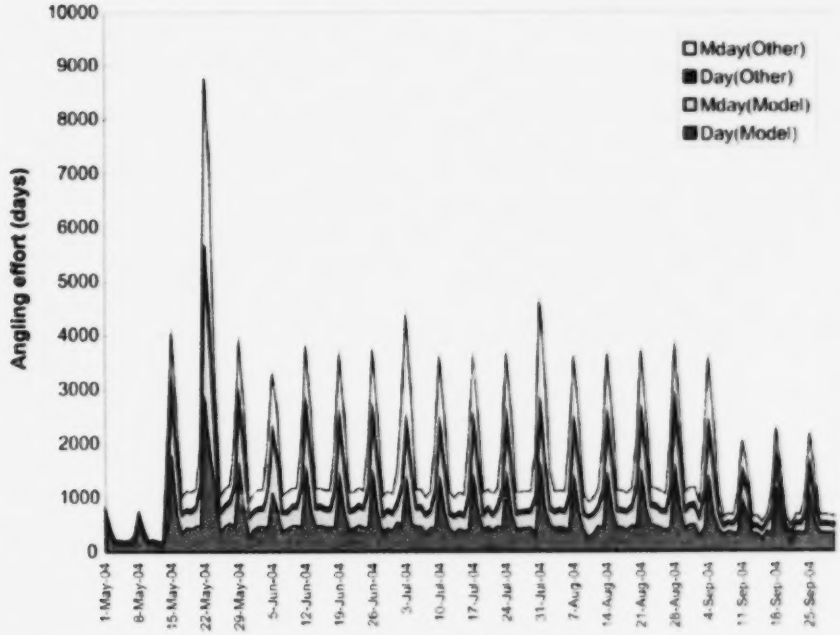


Figure 11. Expected (actual vs. modelled) angling effort (multiple day (Mday) vs. day) by trip type for the Thunder Bay area in summer 2004.

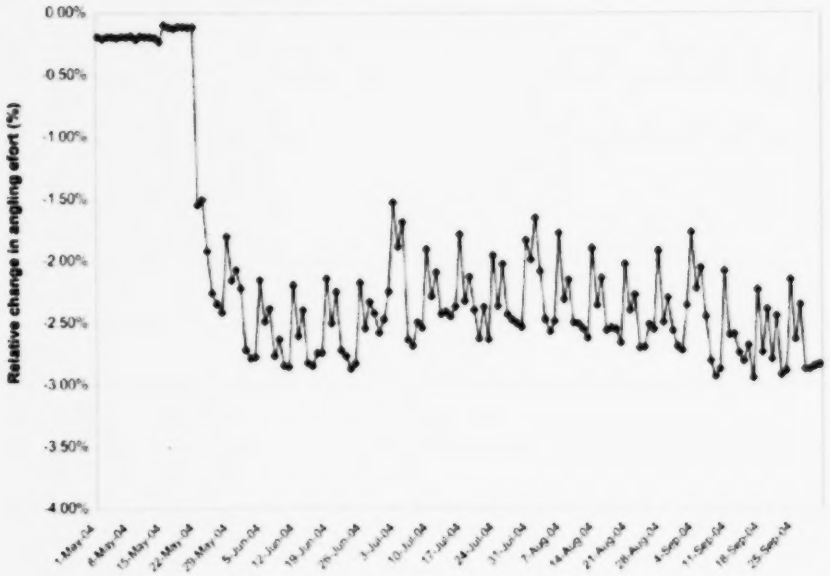


Figure 12. Forecasted relative changes to daily angling effort from lake trout extirpation scenario in the Thunder Bay area.

water season for lake trout commences for most of the study waters. Consequently, the models predict that the relative change in angling effort would range between -1.5% to -3%. This variability arises from temporal events that affect either the expected utility among fishing sites (e.g., the availability of other fish species) or the decision to participate in recreational fishing (e.g., weather, holidays, etc.). The largest relative changes are on Mondays through Thursdays of the week.

Besides temporal changes to the expected angling effort from the scenario, the model can also forecast spatial changes in angling effort.[15] However, these forecasts are only available for modelled day and multiple-day fishing trips since there is no model that links other fishing trips to specific locations.

We first present the expected spatial pattern of angling effort from the model before the scenario change (see Figure 13). The model expects angling effort to be greatest on Lake Superior and large walleye lakes with easy access that were within 200 km of Thunder Bay. This static pattern, however, masks some important temporal dynamics. For example, while Lake Superior tributaries are expected to receive a small amount of angling effort, almost all of this effort occurs in May. As a result, the relative use of Lake Superior tributaries is very high before the start of the open water walleye season.

The forecasted effects of the lake trout scenario on angling effort at the various fishing sites are shown in Figure 14. To provide a fair comparison among the fishing sites, we reported the relative change in angling effort.

The figure conveys three important pieces of information. First, as expected, waters with lake trout populations are forecasted to have reduced relative angling effort. In fact, angling effort in these lakes may be reduced to 40 to 50% of current effort. Second, by taking a landscape approach, the model redistributes some of this lost angling effort among other fishing sites (see triangles on Figure 14). Finally, the model accounts for the propensity of anglers to substitute their fishing trips to nearby fishing sites. The figure shows that relative increases to angling effort are greater at sites closer to the waters with lake trout than at more distant waters. This spatial effect is a direct result of the *DS_ALL* parameter estimate (see Table 5) that captured complex substitution among fishing sites.

[15]Actually, the model can provide estimates of spatio-temporal changes as well.

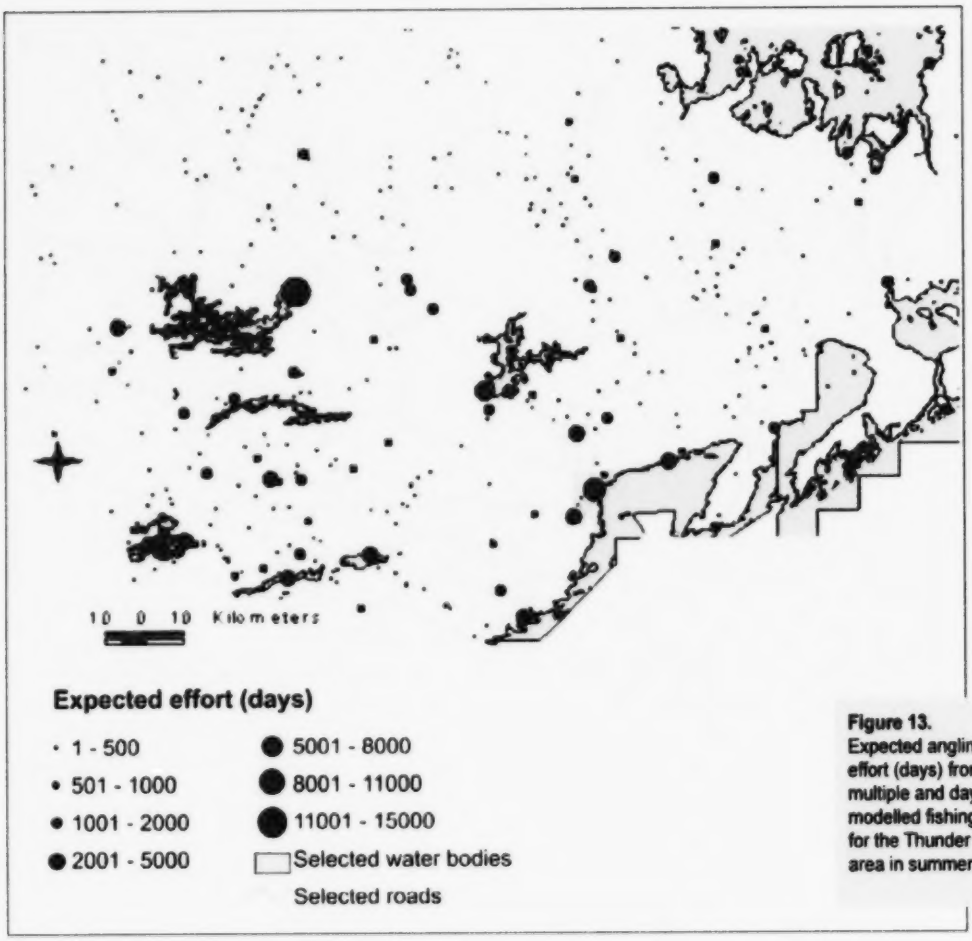


Figure 13. Expected angling effort (days) from multiple and day modelled fishing trips for the Thunder Bay area in summer 2004.

The scenario of lake trout extirpation provides an illustration of the forecasting potential of our repeated nested logit model. The model provided forecasts about the effects of the scenario on the amount, timing, location, and economic value of recreational fishing in the Thunder Bay area. Other researchers may use this model to assess the effects of many different scenarios, including those most likely to arise through climate change.

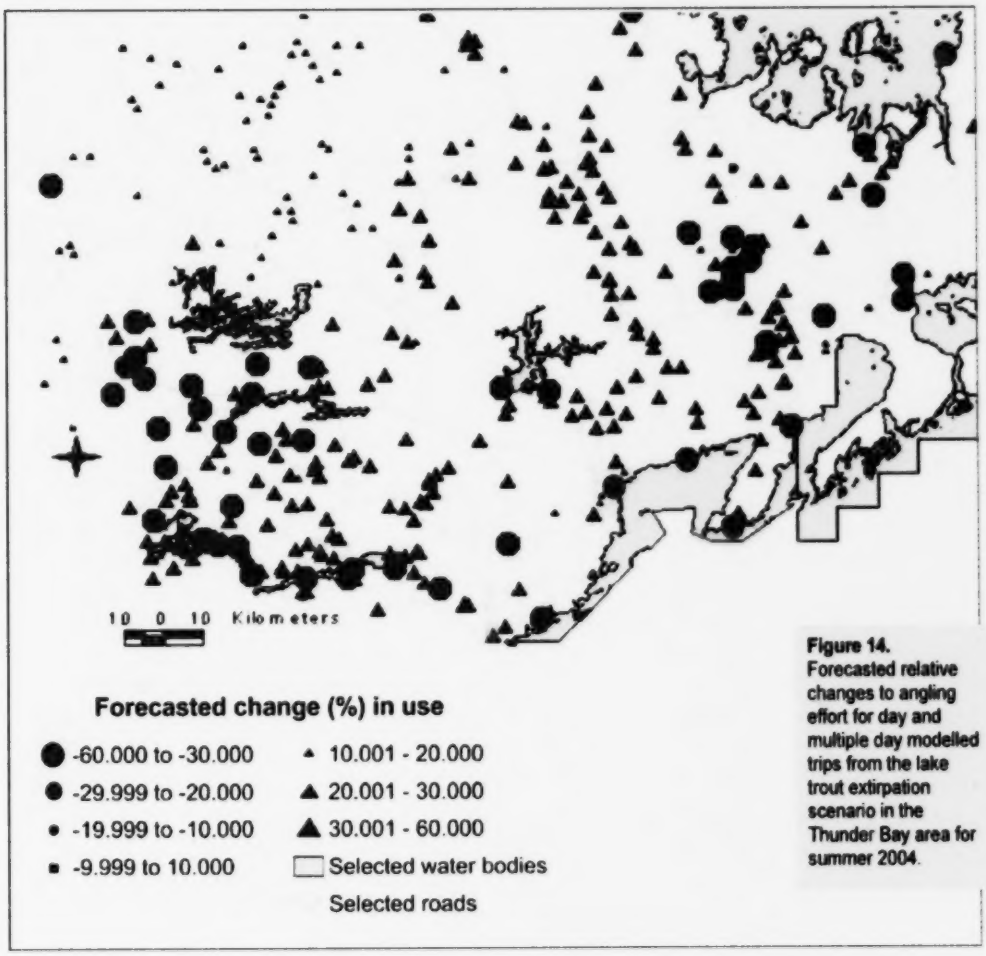


Figure 14. Forecasted relative changes to angling effort for day and multiple day modelled trips from the lake trout extirpation scenario in the Thunder Bay area for summer 2004.

6. Conclusions

Our study was conducted to develop a predictive model that could account for the effects of climate change on the availability and attractiveness of fishing alternatives. We used a repeated nested logit model to predict the amount, timing, and location of fishing trips in the Wawa and Thunder Bay areas. Forecasts relating to the frequency, timing, location, and economic value of fishing trips were also illustrated for a modelled lake trout extirpation scenario in the Thunder Bay area.

We estimated the potential effects of climate on attractiveness of fishing alternatives through temporal and spatial attributes. Our attempts to model the effect of weather on participation choices led to the finding that participation was negatively associated with expected maximum temperature. While it is likely that this finding is spurious, the result does suggest that changes to temperatures without subsequent changes to fishing quality will likely have little impact on fishing decisions. By contrast, changes to the amount and timing of precipitation are likely to greatly affect the decisions of anglers to participate in day fishing trips.

Climate has great potential to affect the attractiveness of fishing sites through changes to the abundance and availability of fish species. As illustrated through the lake trout scenario, any impact from climate that affects the availability of fish species will likely have the greatest impact on anglers' fishing behaviours. This potential impact is likely greatest on any threats or expansions to the availability and abundance of walleye. For example, an increase in mean temperatures that increases the productivity of northern Ontario lakes for walleye will likely provide short-term benefits for area anglers. It is, however, an empirical question as to whether increased angler exploitation of walleye may remove any potential long-term benefits from this scenario. Changes to seasonal closures of walleye will also likely greatly affect the welfare of recreational anglers.

Potential impacts on the availability and abundance of other fish species will also impact most anglers. Some anglers prefer to target cold water fish species such as trout and char. Changes to the availability of these species will likely force these anglers to either travel further or to target other fish species. Therefore, declining trout fishing opportunities could affect anglers who target walleye by having trout anglers spend more time catching walleye. Our lake trout extirpation scenario forecasts suggested that many anglers would substitute their fishing from lakes with lake trout to nearby waters with other fish species. This substitution could affect the sustainability of fish populations in these nearby waters. Furthermore, rainbow trout is a very important species to many anglers during the time before the open water season for walleye and as ice conditions become less safe on area lakes. Any impact to the abundance of the rainbow trout in Lake Superior tributaries will negatively impact many anglers.

Changes to snow and ice conditions are unlikely to impact angler effort on northern Ontario water bodies. It appears that culture, tradition, and the seasonal availability of walleye are all much more important to anglers than are ice and snow conditions. Again, if shortened ice cover on waters resulted in earlier walleye spawning and an earlier walleye open water season date, anglers would largely benefit in the short term.

Weather is unlikely to affect fishing trip participation by anglers. Multiple-day fishing trips appear to be guided more by culture and tradition than weather. Most of these multiple-day fishing trips occurred between the Victoria and Labour Day weekends, which define the summer season for most northern Ontarians. Warmer weather will not likely affect this pattern of effort since constraints such as children's summer vacations and amount of personal vacation time available to adults are unlikely to change.

Angler participation in day fishing trips on Crown lands was also affected more by culture and tradition than weather. Again, most of these day trips commence with the start of the walleye open water season. Unlike maximum temperatures, changes to precipitation have the potential to impact participation in day fishing trips. Increases or decreases in precipitation that result from climate change will, thus, likely affect the number and timing of day fishing trips on Crown Lands.

The site choice and participation models presented represent the beginning rather than the conclusion of an investigation of climate change on recreational fishing. The models are developed to provide forecasts related to the number, timing, and location of fishing trips and the economic value of recreational fishing. As such, researchers may apply our models to forecast the likely impacts of a range of climate change scenarios on recreational fishing in northern Ontario. Efforts are underway to develop these participation and site choice models into a spatially explicit decision support system. Over time, we hope to refine the decision support system to account for dynamic effects among anglers and fisheries and to capture the limited awareness that many anglers have about available fishing opportunities.

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Appendix 1. Technical modelling details

Predicting expected catch from the tobit model

The expected walleye catch rates for each alternative (i), angler (n), and each trip ($E(W\_CUE_{in})$) were estimated from the parameter estimates (γ), a sigma value (σ) that accounts for variability among the residuals (see Table 2), and fishing site attribute measures ($\mathbf{Z}$). These catch rate estimates require transformations based on the normal cumulative (Φ) and probability (φ) density functions (see equation 1). While this estimation will introduce some bias since walleye catch rate estimates contain error (Morey and Waldman 1998), it is a better approach than ignoring the catch rate attribute.

$$E(W\_CUE_{in}) = \Phi\left(\frac{\mathbf{Z}_{in}\gamma}{\sigma}\right)\left[\mathbf{Z}_{in}\gamma + \sigma\left(\frac{\phi\left(\frac{\mathbf{Z}_{in}\gamma}{\sigma}\right)}{\Phi\left(\frac{\mathbf{Z}_{in}\gamma}{\sigma}\right)}\right)\right]$$

Predicting fishing site choices

Equation 2 may be used to estimate the probability that angler n will choose alternative i for a modelled trip context.

$$P_{in} = \sum_{m=1}^{M}\left[\frac{\left(\alpha_{im}e^{\beta_i' \mathbf{X}_{in}}\right)^{\frac{1}{\mu}}\left(\sum_{j=1}^{J_m}\left(\alpha_{jm}e^{\beta_j' \mathbf{X}_{jn}}\right)^{\frac{1}{\mu}}\right)^{\mu-1}}{\sum_{l=1}^{M}\left(\sum_{j=1}^{J_l}\left(\alpha_{jl}e^{\beta_j' \mathbf{X}_{jn}}\right)^{\frac{1}{\mu}}\right)^{\mu}}\right]$$

The probability (P) that individual n will select alternative i depends upon exponent of the summation of parameter estimates from Table 5 (β_i) multiplied by the corresponding fishing site attributes ($\mathbf{X}_{in}$). This sum is divided by the summation of these exponents over all alternatives (J) available to the individual. This cross-nested logit model also includes the terms α and μ and the summation over M nests (i.e., groups). The α represents the allocation of an alternative to the m_{th} nest. The μ is the dissimilarity parameter from Table 5 that introduces correlation among the unobserved utilities of the alternatives within each nest.

Estimating expected maximum utility from the site choice models

Equation 3 can be used to estimate the expected maximum utility from the fishing sites for angler n and day d.

$$IV_{nd} = \ln\left(\sum_{m=1}^{M}\sum_{i=1}^{J}\left(\alpha_{im}e^{\mathbf{X}_{i\_nd}\beta}\right)^{\frac{1}{\mu}}\left(\sum_{i=1}^{J}\left(\alpha_{im}e^{\mathbf{X}_{i\_nd}\beta}\right)^{\frac{1}{\mu}}\right)^{\mu-1}\right)$$

The notation is the same as for equation 2, with M nests, J fishing alternatives, β_i the parameter estimates from Table 5, X_{im} measures of fishing site attributes, α the allocation of an alternative to the m_{th} nest, and μ the dissimilarity parameter from Table 5. This utility measure is estimated separately for each angler and each fishing day for both multiple and day fishing trips and for both Wawa and Thunder Bay area anglers.

Predicting participation in multiple or day trips

The same model is used to estimate the probability that an angler will select a day or multiple day fishing trip (see equation 4). This multinomial logit model is used to predict the probability that angler n will choose alternative k (modelled multiple day trip, other multiple day trip, no multiple day trip) on day d. For day trips, the alternatives include modelled day trip, other day trip, and do not fish.

$$P_{knd} = \frac{e^{\delta_k' V_{knd} + \tau IV_{knd}}}{\sum_{l=1}^{K} \left(e^{\delta_l' V_{lnd} + \tau IV_{lnd}} \right)}$$

The model form is simpler than the cross-nested logit from equation 2. The IV term is the expected maximum utility measure estimated from equation 3, while τ is a parameter estimate for the expected maximum utility (see Table 7). The matrix $\mathbf{V}$ represents the attributes that describe a participation alternative, angler, and given day. The parameters δ come from Table 7.

Joint predictions of participation and site choice

The joint prediction of participation and site choice decisions rely upon all previous equations. For multiple day trips, the probability that an angler n will select a modelled multiple day fishing trip (k) to alternative i on day d, equals the product of equation 4 and a conditional probability of equation 2 (see equation 5). The condition simply ensures that the angler has selected alternative k on day d. Equation 1 is used to estimate the angler's expected walleye catch for the alternatives on day d, which becomes an attribute in the site choice model. The expected maximum utility estimate from equation 3 enters the participation model as an attribute.

$$P_{iknd} = P_{knd} * (P_{in} \mid kd)$$

When predicting the probability of a day trip, one must expand equation 5 to include the probability that an angler does not first choose a multiple day fishing trip. Equation 6 achieves this expansion by including the P_{qnd}, which is the probability that an angler selects alternative q (does not take a multiple day fishing trip) from equation 4. The remaining two probabilities are conditioned so that an angler selects this no multiple day fishing alternative.

$$P_{iknd} = P_{qnd} * (P_{knd} \mid q) * (P_{in} \mid qkd)$$

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